5.0 INSPECTION OF EMBANKMENT DAMS

5.1 INTRODUCTION

The purpose of a dam inspection is to identify deficiencies that potentially affect the safety of the dam. For that reason, inspections are usually referred to as dam safety inspections. As described in previous chapters, there are four types of dam safety inspections that typically will be performed: formal technical, maintenance, informal, and special. This chapter covers all four types of inspections on embankment dams, but focuses on the embankment structure only. Additional embankment dam features, such as spillways, outlets, and general areas are covered under subsequent chapters.

The purpose of this chapter is to help owners and inspectors identify conditions that threaten the safety and long life of the dam. Although some of these conditions can be corrected by normal maintenance, more serious deficiencies may require further investigation by qualified professionals with expertise in specific areas of concern. The end of this chapter contains sketches that can be used to help the owner or inspector identify and classify problems found on the embankments of dams.

Embankment dams include any dam constructed of natural soil materials. This includes the following general types of dams:

Earth Dam (or earthfill dam) - An embankment dam in which more than 50% of the total volume is formed of compacted inorganic soil material obtained from a borrow area (see Figure 5-1).

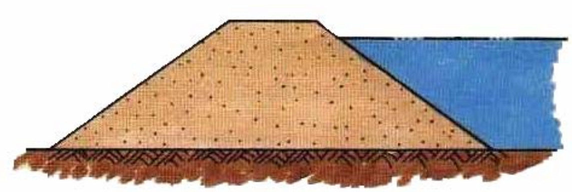


Figure 5-1 Earth embankment dam.

Homogeneous Earthfill Dam - An embankment dam constructed of similar earth material throughout, except for possible inclusion of internal drains or drainage blankets; distinguished from a zoned earthfill dam.

Hydraulic Fill Dam - An embankment dam constructed of materials, often dredged, that are conveyed and placed by suspension in flowing water (rare). Hydraulic fill dams are not recommended and are prone to instability problems.

Rockfill Dam - An embankment dam in which more than 50% of the total volume is comprised of compacted or dumped pervious natural or crushed rock.

Rolled Fill Dam - An embankment dam of earth or rock in which the material is placed in layers and compacted by using rollers or rolling equipment.

Zoned Embankment Dam - An embankment dam, which is composed of zones of selected materials having different degrees of porosity, permeability, and density.

The visual inspection procedures and information presented in this chapter can be applied to all the various types of embankment dams encountered. The information is presented for each feature of the embankment, including the crest, upstream slope, downstream slope, abutments, and groins.

The conditions or problems that may be encountered on embankments can vary depending on the location. For example, seepage typically occurs on the downstream slope areas and in the abutments and groins, whereas beaching and damage from wave action occur on the upstream slope. Some types of problems can develop anywhere on the embankment, such as inappropriate vegetative growth, cracking, or erosion. Tailwater on the downstream slope of an embankment can saturate the soils and lead to embankment instability; the potential for backwater should be considered.

Typically, the cause of the problem and potential safety concerns should be determined before any repairs are made on dams. However, if the problem is severe or an emergency is developing, emergency response actions may be required immediately. Short-term repairs, downstream notification, and other measures may be required in such instances (refer to Part 2). Short term measures may include water level lowering, embankment stabilization, spillway enlargement, or controlled breaching if the situation becomes critical.

Inspecting dams to identify and resolve the concerns addressed in this chapter can minimize or eliminate the chance of dam deterioration or failure. The inspector should be on the lookout at all times for any conditions that could contribute to dam failure.

5.2 ITEMS OF CONCERN

Some of the more common conditions that may be encountered during visual inspection of the embankment include longitudinal and transverse cracking, desiccation cracking, depressions, settlement, slides, seepage, lack of protection from wave action, erosion, inappropriate vegetation, tree root penetration, poor maintenance, ponding water, animal burrows, and debris. Many of these concerns are interrelated and occur in conjunction or as a result of each other.

The dam inspector should visualize worst-case conditions when looking for potential problem areas. For example, he/she should consider maximum loadings on roads and other structures, maximum water levels in the reservoir, peak discharge rates from spillways, discharge through the emergency spillway, winter icing conditions, etc.

The dam's crest usually provides the primary access for visual inspection and maintenance. Since surface water will pond on the crest unless that surface is well maintained, this part of the dam may require periodic regrading. Problems found on the crest should not be graded over without determining the cause. When a questionable condition is found, it should be evaluated and a qualified dam safety professional should be consulted if necessary. Quick corrective action applied to conditions requiring

Figure 5-2 Embankment slope inspection can be hindered with excessive vegetation.

attention will promote the safety and extend the useful life of the dam while possibly preventing costly future repairs.

The upstream slope needs a thorough visual inspection, since the slope protection, vegetation, debris, and reservoir water can hide problems. Anytime the reservoir is emptied, the slope should be thoroughly inspected for settlement areas, animal burrows, sinkholes, or slides. Also, the reservoir basin (bottom of the reservoir) should be inspected for sink holes or settlement anytime the reservoir is emptied.

The downstream slope is especially important during visual inspection because it is the area where evidence of developing problems appears most frequently. The downstream slope requires especially detailed visual inspection. In order to assure the safety of the dam, it is important to keep this area free from obscuring vegetative growth. When cracks, slides or seepage are noted in this area, the cause should be determined and corrective action should be recommended immediately.

5.3 CRACKS AND SLIDES

5.3.1 Overview

Figure 5-3 Longitudinal cracks on embankment slope.

Cracks and slides may indicate serious problems within the embankment. Looking for and spotting cracks may be difficult. The slope must be traversed in such a manner that the inspector is likely to walk over the cracks. If the embankment is covered with heavy brush or vegetation, a more concentrated search must be made to identify cracks. Slides are usually easy to identify.

Cracks on embankments are divided into three categories in this chapter: longitudinal cracks, transverse cracks, and desiccation cracks. Cracks in the embankment are often the beginning of a slide, and cracks further weaken the soil strength by allowing more water to enter the embankment. To help distinguish drying (desiccation) cracks from other types of cracks, the ground surface adjacent to the dam should be examined for similar cracking patterns. Cracks should always be taken seriously, and the cause of the cracking should be determined so that the correct remedy can be developed.

Cracks may be only an inch or two wide but 2 or 3 feet deep. Usually a depth of 2 or more feet indicates that a serious condition is present. Shallow cracks may be harmless desiccation cracks. All cracks over 12 inches deep should be closely inspected and evaluated.

Cracks may indicate possible foundation movement or failure, the beginning of embankment failure, or a surface slide. For example, a 20-foot-long line of recently dislodged riprap along the upstream slope could indicate a crack underneath the riprap.

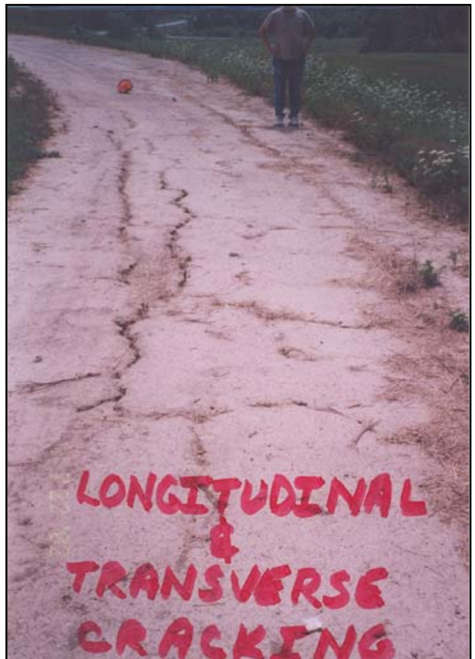


Figure 5-4 Inspection photograph indicating longitudinal and transverse cracking on crest of embankment.

5.3.2 Longitudinal Cracks

Longitudinal cracking may indicate localized instability, differential settlement, foundation settlement, and movement between adjacent sections of the embankment. In recently built structures, longitudinal cracks may indicate inadequate compaction of the embankment during construction. This form of cracking can occur anywhere on an embankment. Longitudinal cracking is characterized by a single crack or a close, parallel system of cracks along the crest or slope in a direction more or less parallel to the length of the dam. These cracks, which are continuous over their length and are usually greater than 1 foot deep, can be differentiated from drying cracks which are usually intermittent, erratic in pattern, shallow, very narrow, and numerous. Longitudinal cracking usually signals the early stages of a slide or slough, and may precede vertical displacement as the dam attempts to move to a position of greater stability. In this case, the crack usually develops into a scarp which forms during movement of unstable slopes. Vertical displacements on the crest are usually accompanied by displacements or bulging on the upstream or downstream faces of the dam.

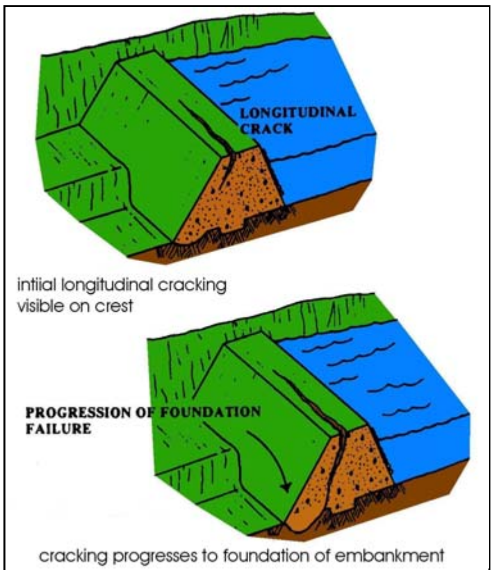


Figure 5-5 Longitudinal cracking may indicate foundation failure.

Longitudinal cracks can allow stormwater and reservoir water to enter the embankment. When water enters the embankment, the strength of the embankment material adjacent to the crack may be lowered. The lower strength of the embankment material can lead to or accelerate slides and slope stability failure.

Longitudinal cracks usually get worse with time due to rainfall, seepage, and the decreasing strength of the embankment and foundation materials. When the soil is weakened sufficiently, or the soil below the crack becomes saturated, sloughing or sliding will occur. As the soil becomes saturated it gets heavier, resulting in an increased tendency for the soil mass to move downward. Weakening and removal of foundation materials by water movement will also cause increased settlement of the embankment resulting in increased cracking.

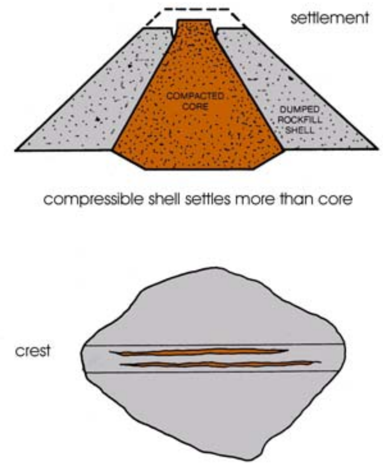


Figure 5-6 Longitudinal cracking due to differential embankment settlement.

If longitudinal cracking is observed during a visual inspection, the following actions should be taken:

- Photograph and record the location, depth, length, width, and offset of each crack observed. Stakes should be placed at the ends of the cracks, and the distance between the stakes measured and recorded. Compare observations with previous results.
- Closely monitor the crack for changes and scarping.
- Recommend appropriate corrective action be taken to repair or to replace the damaged slope or crest areas.
- Consult a qualified dam safety professional to determine the cause of the cracking if it is severe, or gets progressively worse.

5.3.3 Transverse Cracks

Transverse cracking may indicate differential settlement or movement between adjacent segments within the embankment or the underlying foundation. Transverse cracking is usually a single crack or a close, parallel system of cracks which extend across the crest in a direction more or less perpendicular to the length of the dam. This type of cracking is usually greater than 1 foot in depth and can easily be distinguished from drying cracks. Transverse cracking poses a definite threat to the safety and integrity of the dam. If the crack should progress to a point below the reservoir water surface elevation, seepage could occur along the crack and through the embankment cross-section. This could evolve into a piping situation, and if not corrected, lead to breaching of the dam.

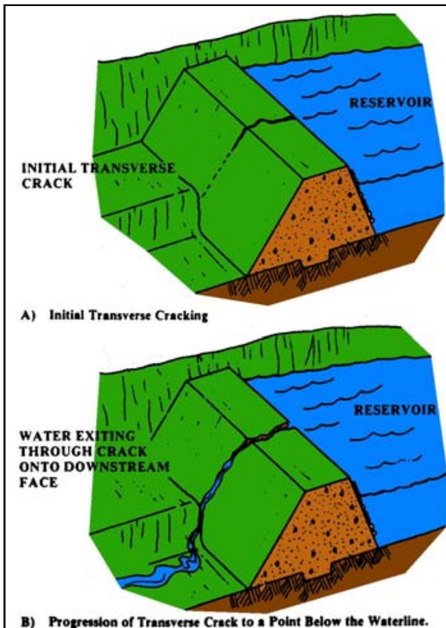


Figure 5-7 Progression of transverse cracking.

Transverse cracking frequently develops when compressible material overlies abutments consisting of steep or irregular rock, or when areas of compressible or erosive material are in the foundation. Soft or weathered rock formations in the foundation may collapse or erode from ground water action, leading to embankment settlement. Limestone is another potentially hazardous foundation material that can dissolve in groundwater, creating voids that can lead to embankment settlement. For this reason, dams in karst areas may be particularly hazardous.

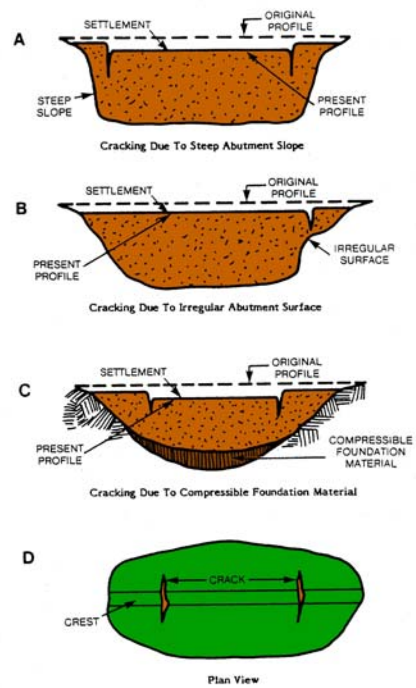


Figure 5-8 Transverse cracking due to differential settlement within embankment.

If transverse cracking is observed during a visual inspection, the following actions should be taken:

- Photograph and record location, depth, length, width, and offset of the cracks. Stakes should be placed at the ends of the cracks, and the distance between the stakes measured and recorded.
- Closely monitor the cracks for changes.
- Recommend appropriate corrective action be taken to repair or to replace the damaged slope or crest areas.
- Consult a qualified dam safety professional to determine the cause of the cracking if it is severe or gets progressively worse. Serious cracking or repair operations usually require lowering the reservoir level.

5.3.4 Desiccation Cracks

Desiccation cracking is caused by the drying out and shrinking of certain types of embankment soils, usually highly plastic soils that contain a large percentage of clay. Desiccation cracks usually develop in a random, honeycomb pattern on the crest and the downstream slope. Desiccation cracks may be oriented longitudinally or transversely, or both. This type of cracking may also develop on the upstream slopes above the water level. Although not normally used in embankment construction, silts will also display desiccation cracking if exposed to drying. As an example, desiccation cracking can be observed in "mud puddles" that completely dry out, leaving behind a series of cracks in the bottom of the puddle.


Figure 5-9 Desiccation cracking.

The worst desiccation cracking develops when a combination of the following two factors is present:

(1) A hot, dry climate accompanied by long periods in which the reservoir remains lowered or empty.
(2) An embankment that is composed of highly plastic soil, such as clay.

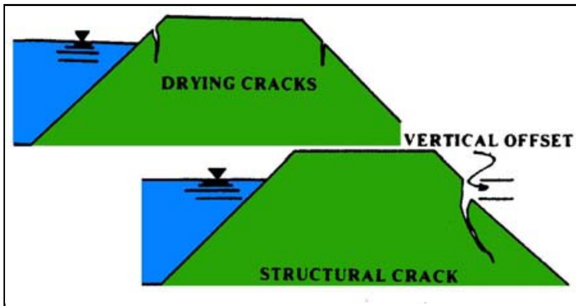


Figure 5-10 Desiccation cracks are much smaller than structural cracks.

Usually, desiccation cracking is not harmful unless it becomes severe. The major threat of severe desiccation cracking is that this type of cracking can contribute to the formation of gullies. Surface runoff erosion concentrating in the desiccation cracks or gullies can result in eventual damage to the dam. Also, heavy rains can fill up these cracks and cause portions of the embankment to become unstable and to slip along crack surfaces where the water has lowered the strength of the embankment material. Deep cracks that extend through the core conceivably can cause a breach of the dam when the reservoir rises and the cracks fail to swell rapidly enough to reseal the area.

If desiccation cracking is observed during a visual inspection, the following actions should be taken:

- Probe the more severe cracks to determine their depth.
- Photograph and record the location, depth, length, and width of any severe cracks observed.
- Compare the measurement of the crack dimensions with past measurements to determine if the condition is worsening.
- Recommend appropriate corrective action be taken to repair or to replace the damaged slope or crest areas. Usually repairs by sealing and grading are adequate.
- Consult a qualified dam safety professional to determine the cause of the cracking if it is severe or gets progressively worse.

5.3.5 Slides

Slides have various names including displacements, slumps, slips, and sloughs. Slides can be grouped into two major categories: shallow slides and deep-seated slides. Shallow slides are called sloughs, or sloughing. Slides develop when the strength of the soil in the embankment is less than the forces that cause slope failure. Steep embankment slopes, poor soil compaction, improper soil composition, excessive water in the soil, and seepage contribute to slides.

Shallow slides on the upstream slope are often the result of an overly steep slope and/or poorly compacted soils. These conditions can be aggravated by a rapid lowering of the reservoir. Shallow slides on the upstream slope usually pose no immediate threat to the integrity of the dam. However, shallow slides may lead to the obstruction of water conveyance structure inlets and larger, deep-seated slides.

Figure 5-11 Shallow slide at toe of embankment resulting from excessive seepage and poor compaction.

Shallow slides on the downstream slope also indicate an overly steep slope or poorly compacted soils. In addition, these slides may also indicate a loss of strength in the embankment material. A loss of strength in the embankment material can be the result of saturation of the slope from either seepage or surface runoff. Additional loads from snow banks or structures can aggravate the condition. The owner or inspector should consult a qualified dam safety professional if he/she is unsure whether the slide presents a serious threat to the integrity of the dam.

Deep-seated slides are serious threats to the safety of the dam. Deep-seated slides may be recognized by the presence of a well-defined scarp or bulging on the slope or at the toe. Arc-shaped cracks on the slope are usually indications that a slide is beginning. This type of crack may develop into a large scarp at the top of the slide.

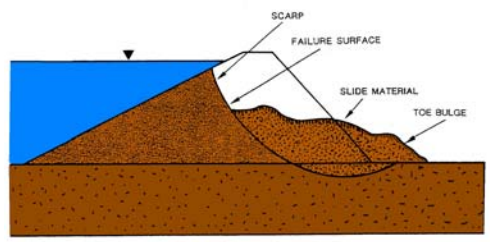


Figure 5-12 Deep-seated slide.

Bulging is usually associated with the lateral spreading of the dam or with slides. Bulging as a result of lateral deformation is accompanied by settlement of the crest. The bulging is most evident at the toe of the dam. A toe bulge due to lateral spreading may result in some loss of freeboard. If the inspector suspects a loss of freeboard, a survey of the crest should be performed to verify if there has been a loss of freeboard. The area above a bulge should be examined carefully in order to identify other indicators of instability such as cracks and scarps. Not all bulges indicate a stability problem. When the dam was constructed, it may not have been uniformly graded by the dozer or grader operator, so there may be bulges in the embankment that were formed during construction. The inspector should determine the cause of the bulging and recommend a course of action. Bulging associated with slides is a more serious problem. If bulging associated with cracks or scarps is observed, a qualified dam safety professional should be contacted immediately.

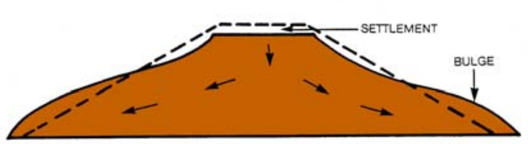


Figure 5-13 Bulging and associated crest settlement.

Slides are usually easy to spot and require immediate evaluation by a qualified dam safety professional if they are large or are continuing to show movement. However, slides may be difficult to spot if a scarp has not developed. Their appearance may be subtle, since there may be very little settlement or bulging out from the normal slope. A good familiarity with how the slope looked at the end of construction will help identify any new slides. Figures 5-11 and 5-14 illustrate slides on the downstream slope, with vertical and horizontal movement, and the formation of a scarp.

Figure 5-14 Large slide on embankment with prominent scarp.

Most slides have early warning signs that allow their detection. They usually develop over a period of time, beginning with some form of surface cracking, followed by measurable vertical displacement and scarping, and potentially ending in complete failure of the embankment or slope. A bulge in the embankment and vertical displacement at a crack in the embankment are usually signs of sliding. Stormwater falling onto or running into the slide area may make conditions worse and accelerate the instability of the slope. Longitudinal and arc-shaped cracks are usually a symptom of impending slides.

If a slide or bulge is observed during a visual field inspection, the following actions should be taken:

- Photograph and record the location, depth, length, width, and height of scarp for each slide or bulge observed. Stakes should be placed at the ends of the scarp, and the distance between the stakes measured and recorded.
- Look for any surrounding cracks, especially uphill from the slide.
- If a bulge is present, closely inspect the area above the bulge for cracking or scarps which indicate that a slide is the cause. Probe the bulge to determine if material is excessively moist or soft. Excessive moisture or softness usually indicates that a slide is the cause.
- Look for evidence of seepage or saturated soils in or below the slide. Probe the entire area to determine the condition of the surface material.
- Closely monitor the slide for changes.
- Consult a qualified dam safety professional to determine the cause of the slide if it is severe.
- Recommend appropriate corrective action be taken to repair or to replace the damaged slope or crest areas.
- In most instances, deep-seated slides will require the lowering or draining of the reservoir to prevent the possible breaching of the dam.

5.4 DEPRESSIONS


Figure 5-15 Settlement on embankment crest.

Depressions can be minor or they can be very serious. Sinkholes are a serious type of depression and are cause for alarm. A good way of distinguishing between minor depressions and sinkholes is to look at their profiles. Minor depressions have gently sloping, bowl-like sides, while sinkholes usually have steep, bucket-like sides. Some areas that appear to be depressions may be the result of improper final grading following construction. Settlement on the crest is a serious form of depression that can result in lowering of the embankment, creating a potential for overtopping. Although most minor depressions do not represent an immediate danger to the dam, they may be early indicators of more serious problems. Depressions may also result in water ponding on the crest of the embankment which may lead to stability problems due to soil saturation in the embankment.

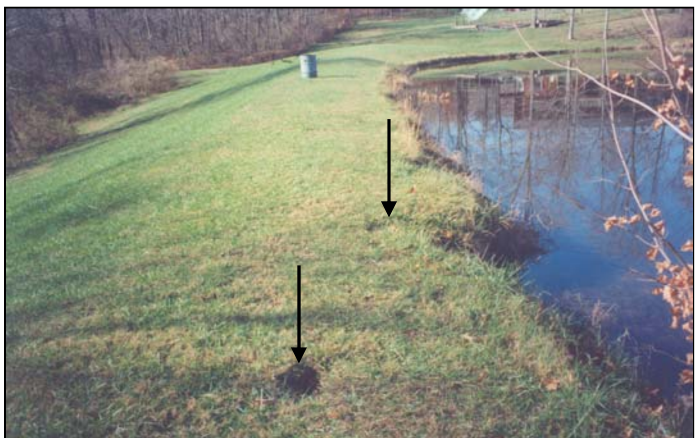


Figure 5-16 Sinkholes developing from muskrat burrows.

Depressions can be serious safety concerns and are typically caused by:

- Localized settlement in the embankment or foundation.
- Embankment spreading in the upstream and/or downstream direction. This type of spreading may result in a loss of freeboard or reservoir capacity, and can cause overtopping of the dam.
- Erosion - wave action against the upstream slope that removes embankment fines or bedding from beneath riprap may form a depression as the riprap settles into the vacated space. This may only appear on the upstream slope, or may spread to the crest if the damage is severe.
- Piping – soil piping may cause surface soils to collapse into the voids created by the piping, creating sinkholes.
- Animal burrows – surface soil falling into animal burrows can create depressions or sinkholes.

Depressions and other misalignments in the crest (and embankment slopes) often can be detected by sighting along fixed points. The inspector should sight and take photographs along guardrails, parapet walls, or pavement striping. Some apparent misalignment may be due to irregular placement of the fixed points. For this reason, irregularities should be evaluated over time to verify suspected movement. Sighting irregularities is facilitated by surveying permanent monuments across the crest to determine the exact location and the extent of misalignment. A record of survey measurements also can establish the rate at which movement is occurring.

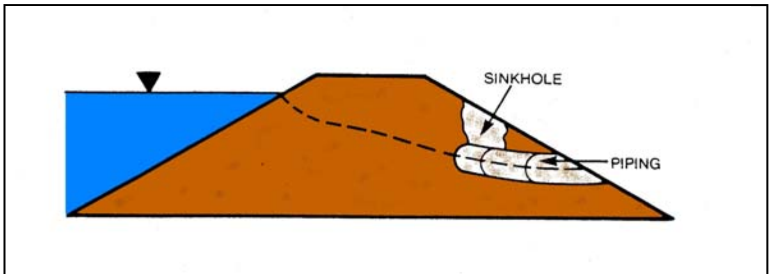


Figure 5-17 Sinkhole caused by animal burrow.

Sinkholes are a serious type of depression that can result in hazardous embankment safety conditions. Sinkholes are formed when the removal of subsurface embankment or foundation material has caused overlying material to collapse into the resulting void. The presence of a sinkhole may indicate that material has been transported out of the dam or foundation through the process of piping. In addition, animal burrows, and flowing water under pipes, walls, and slabs can contribute to the formation of sinkholes. The decomposition of embedded wood or other vegetative matter in the embankment also can cause sinkholes. If the embankment depressions or settlement progresses to a level below the normal pool elevation, the reservoir may overtop the embankment, resulting in breaching or total embankment failure. Settlement also reduces the storage capacity and freeboard of the dam which could result in overtopping, breaching, or failure during storm events.

If a depression is observed during a visual inspection, the following actions should be taken:

- Photograph and record the location, size, and depth of the depression.
- Probe the floor of the depression to determine whether or not there is an underlying void. An underlying void is indicative of a sinkhole.
- Frequently observe the depression to monitor its development.
- Consult a qualified dam safety professional to determine the cause of the depression if it is severe, or gets progressively worse.
- Recommend appropriate corrective action be taken to repair or to replace the damaged slope or crest areas.

5.5 INADEQUATE SLOPE PROTECTION

Slope protection is designed to prevent erosion of the embankment slopes, crest, and groin areas. Inadequate slope protection usually results in deterioration of the embankment from erosion, and in the worst cases, can lead to dam failure. The inspector should look for inadequate slope protection, including eroded and displaced materials, and lack of vegetation during every visual inspection.

Figure 5-18 Riprap protection on the embankment slope at the shoreline, with grass on the rest of the slope.

The two primary types of slope protection used on embankment dams include vegetative cover (grass) and riprap (rock). Grass cover is usually used on most embankment surfaces, while riprap is commonly used on the shoreline of the upstream slope. Soil cement, concrete, asphalt, articulated concrete blocks, and other types of slope protection also may be used. The type of slope protection selected depends upon economics, how the dam is used, and the prevailing conditions found at the site. A good growth of grass on an embankment provides excellent protection against erosion caused by rainfall and runoff. Deep-rooted grass that can tolerate repeated wetting and drying cycles should be used on embankments. Figure 5-19 shows an embankment experiencing shoreline erosion as a result of inadequate slope protection. The shoreline has no riprap and insufficient vegetative cover.

Figure 5-19 Inadequate slope protection resulting in shoreline erosion.

A lack of vegetative cover or insufficient vegetative cover will result in rapid deterioration of the embankment from erosion. A lack of riprap, or improperly designed riprap along the shoreline can result in erosion of the shoreline soils if riprap is needed to protect the soil against wave action. It should be noted that not all dams will require riprap shoreline protection.

Riprap should be properly sized and placed to provide protection from erosion caused by wind or wave action, surface runoff erosion, and wind scour. Properly designed upstream riprap slope protection is made up of at least two layers of material: (1) an inner filter layer or bedding to keep the underlying soil from washing away; and (2) an outer rock layer to prevent erosion. The inner filter layer could be sand or fine aggregate, or a geotextile.

When deficiencies prevent riprap from providing erosion protection, the soil embankment beneath the riprap is exposed to erosion damage. Undercutting by wave action, slides, and slope failure can lead to failure of the upstream slope, a spillway channel, a plunge pool, or, if erosion continues unchecked, the breaching of the embankment. The inspector should look closely for signs of soil erosion and undercutting in all riprap areas.

If inadequate slope protection is observed, the inspector should:

- Photograph and record the location, size, and extent of the area of concern.
- Determine the cause of the problem, if possible.
- Recommend appropriate corrective action be taken to repair or to replace the damaged areas. Monitor the area if immediate repairs are not feasible (e.g., wrong season for planting grass).

5.6 WEATHERING AND EROSION


Figure 5-20 Erosion rills on the downstream slope of an embankment dam.

Erosion is a natural process, and its continuous forces will eventually wear down almost any surface or structure. Consequently, the dam inspector should always be on the lookout for signs and causes of erosion so that corrective action can be applied to halt its progression. Surface runoff erosion is one of the most common problems on embankment structures. If not corrected, surface erosion can become a more serious problem. During the visual inspection, the inspector should make sure that the slope protection is adequate to prevent erosion. He/she should look for beaching, scarping, and degrading of the slope protection, as well as erosion of the dam soil materials.

The worst damage from surface runoff is manifested by the development of deep erosion gullies on the slopes and groins of both upstream and downstream slopes. Severe gullies can cause breaching of the crest or shorten the seepage path through the dam, possibly leading to piping. Gullies can develop from poor grading or sloping of the crest that leads to improper drainage, causing surface water to collect and to run off at the low points along the upstream and downstream shoulders. Gullies caused by this type of runoff eventually can reduce the cross-sectional area of the dam.

Bald areas or areas where the protective cover is sparse are more susceptible to surface runoff erosion problems. On the upstream slope, erosion may undermine the riprap and cause it to settle. Settlement of the riprap may lead to the eventual degradation of the slope itself.

Shallow erosion rills (less than 6 inches deep) are common on many earth embankments. The formation of rills is difficult to stop, especially on long slopes. Stormwater runoff will tend to concentrate at one or more locations and form preferred flow paths, resulting in surface soil erosion in the form of rills and gullies. Shallow rills usually do not present a safety concern, but they should be monitored and repaired if they worsen. These conditions should be inspected following large or long storm events. Shallow rills will often have grass growing in them, indicating that the problem is minor. If the vegetation has been eroded and removed from the rills exposing the bare soil, the rills will probably get larger every time stormwater runoff flows through them. Repair of rills may do more harm than good to the slopes when trying to repair minor erosion damage, so sound judgment will be needed when recommending and scheduling repairs of this type of damage (e.g., do not perform repairs when the slopes are saturated, or when the damage is minor and does not show signs of accelerated damage).

Even the best designed erosion protection will usually experience some kind of degradation over time. Degraded riprap or other types of embankment protection should be monitored. If evidence shows that serious damage to the embankment is occurring, degraded slope protection must be repaired or replaced.

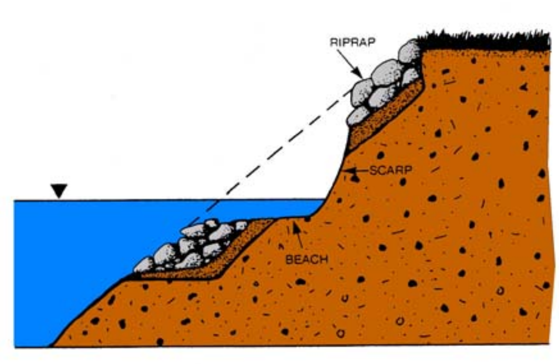


Figure 5-21 Wave action can remove riprap if it is not properly designed. This sketch shows beaching and formation of a scarp.

The constant action of waves on the upstream slope may result in beaching, scarping, and degrading of the slope protection, including riprap. Unless measures are taken to maintain adequate slope protection, wave action may begin to erode the embankment material.

Beaching is the removal of a portion or portions of the upstream slope of the embankment by wave action. Figures 5-21 and 5-22 show the effects of erosion and beaching on the upstream slope of a dam. When beaching occurs, embankment material is deposited farther down the slope. In this extreme form of erosion, the slope protection (i.e., riprap or vegetative cover) and underlying material are removed. A relatively flat beach area with a steep back slope, or scarp, is formed. Scarps should be monitored regularly for additional deterioration and repaired if conditions get worse.


Figure 5-22 Beaching is progressing on an unprotected shoreline

Figure 5-23 Cattle grazing on a dam embankment can lead to erosion problems.

Severe beaching could lessen the width, and possibly height of the embankment, leading to increased seepage, instability, or overtopping of the dam. Riprap installations in areas exposed to numerous freeze-thaw cycles or high winds are most likely to experience problems. The inspector should be alert for riprap problems if the dam is exposed to these conditions.

Adequate erosion protection is also required along the contact between the embankment and the abutments. Runoff from rainfall concentrates in these groin areas and can reach erosive velocities because of the steep slopes. Berms on the upstream or downstream face that collect surface water and empty into the groins add to the runoff volume. The inspector should examine these areas closely.

Erosion adjacent to groins results from improper construction or design, where the finished flow line of the groin is too high with respect to adjacent ground. This condition prevents all or much of the runoff water from entering the groin. The flow concentrates alongside the groin, erodes a gully, and may eventually undermine the lining in the groin. When examining the groins for erosion, the inspector should make sure that: (1) the channel in the groin has adequate capacity; (2) adequate protection and a satisfactory filter have been provided; (3) surface runoff can enter the groin channel; and, (4) its outlet is adequately protected from erosion.

Figure 5-24 Vehicle traffic can kill vegetation and result in erosion.

There are a number of special circumstances that can contribute to or initiate surface erosion of the crest and downstream slope. In some areas, livestock may establish trails on the embankment. Livestock traffic can damage the slope's vegetative cover. Recreational vehicles can cause ruts in the crest and can damage the slope protection. The inspector should be aware of any unique problems that may be common in a particular location or past problems that were noted on previous dam inspections.

During the visual inspection, the inspector should:

- Make sure that the slopes and crest protection is adequate to prevent erosion. Bald areas or areas where the surface protection is sparse are more susceptible to surface runoff problems.

- Look for beaching, scarping, and degradation of riprap or other materials used on the upstream slopes.
- Look for gullies, ruts, or other signs of surface runoff erosion. Be sure to check the low points along the upstream and downstream shoulders and groins since surface runoff can concentrate in these areas.
- Check for any unique problems, such as livestock or recreational vehicles that may be contributing to erosion.

If weathering and erosion are observed, the inspector should:

- Record the findings and photograph the area.
- Determine the extent, severity, and cause of the damage. Measure gullies, rills, and other erosion damage so that its progression can be monitored if necessary.
- Recommend that corrective action is taken to repair the areas damaged by surface runoff and that measures are taken to prevent more serious problems.
- If shorelines need repaired, or extensive embankment excavation is required, the reservoir level may need to be lowered.
- Consult a qualified dam safety professional if necessary.

5.7 INAPPROPRIATE VEGETATIVE GROWTH

Inappropriate vegetative growth is another common embankment problem. Inappropriate vegetative growth generally includes insufficient vegetation, excessive vegetative growth, and deep-rooted vegetation.

Figure 5-25 Trees and brush on an embankment pose a stability risk and can impede visual inspection.

Insufficient vegetation exposes the embankment soil which can lead to accelerated erosion. Insufficient vegetative cover may be a result of soil conditions, environmental conditions, or damage resulting from traffic on the embankment. Soil conditions usually include the lack of sufficient plant nutrients or poor soil composition. Poor soil conditions can be corrected in most cases. Environmental conditions are usually uncontrollable and include extreme heat and dry weather, excessive rainfall, and high winds that can remove fine-grained soils. Repeated vehicular and animal traffic can completely destroy the grass on embankments, leaving bare soil roadways or paths which are susceptible to accelerated erosion if left uncorrected.

Insufficient vegetation on the embankment slopes can progress to serious problems if left uncorrected for extended periods of time. These conditions should be recorded during a visual inspection along with recommendations for corrective action. The recommendations should also include a proposed timeframe for completing the repairs.

Figure 5-26 Insufficient vegetation on embankment crest and slopes will result in accelerated erosion.

Excessive vegetation is a problem wherever it occurs on an embankment dam. Excessive vegetation can obscure large portions of the dam, preventing adequate visual inspection. Problems that threaten the integrity of the dam can develop and remain undetected if they are obscured by vegetation. Excessive vegetation can also prevent access to the dam and surrounding areas. Limited access is an obvious problem both for visual inspection and maintenance, and especially during emergency situations, when access is crucial. Excessive vegetation can provide a habitat for rodents and burrowing animals, posing a threat to embankment dams by creating tunnels and potential seepage paths.

There should be no vegetation in the riprap on the upstream slope. Vegetation in the riprap promotes displacement and degradation of the slope protection. Vegetative growth should be controlled by periodic mowing or other means.

No trees or shrubs should be allowed on any embankment surfaces, or within 25 feet of the abutment contacts. Grass cover should be kept less than 12 inches high at all times. Crown Vetch and Kudzu should not be used on embankment surfaces, and if present, should be removed and replaced with more appropriate grasses.

Figure 5-27 Excessive vegetation around this riser and trash rack makes visual inspection almost impossible.

Although a healthy cover of grass is desirable as slope protection, the growth of deep-rooted vegetation, such as large shrubs and trees, is undesirable. Large trees could be blown over and uprooted during a storm. The resulting cavity left by the root system could reduce the embankment top elevation, breach the dam or shorten the seepage path and initiate piping. Accelerated soil erosion will also develop in the cavity left by an uprooted tree due to the exposed soil surfaces. The cavity left by the uprooting of a tree should be repaired immediately. The method of cavity repair will depend on the size of the tree and the location of the tree on the embankment.

Root systems associated with deep-rooted vegetation (trees, shrubs) develop and penetrate into the dam's cross section, causing damage to embankment and spillway structures. When the vegetation dies, the decaying root system can provide paths for seepage and cause piping to occur. Even healthy root systems of large vegetation can pose a threat by providing seepage paths. These seepage paths eventually can lead to internal erosion and threaten the integrity of the embankment. Generally, trees and shrubs more than 2 feet in height are undesirable growing on or adjacent to embankment dams. The best approach to trees on the crest, slopes, and adjacent to the dam is to cut them down or pull them out before they reach significant size. When and how to remove well-developed trees and root systems that are already in place on the dam depends on the size and location of the tree. If large trees have been cut down, but the stumps and/or root system have not been removed, carefully inspect the areas where the trees were for signs of seepage. The roots that are left behind may rot over time resulting in potential seepage paths. Part 2 of the Indiana Dam Safety Inspection Manual describes methods for removal and repair of trees and their damaging effects.

Figure 5-28 A tree is growing over the top of this spillway conduit.

During the visual inspection, the inspector should:

- Look for excessive and deep-rooted vegetation on all areas of the dam, and within 25 feet of the abutment contacts.
- Look for tress and brush in the spillways, or near conduits.
- Look for insufficient grass covering and bare areas on earth embankments.
- Look for excessive grass growth; grass should be mowed regularly and kept below 12 inches in height.
- Make sure that there is no vegetation growing in the riprap on the upstream slope.
- Check for signs of seepage around any remaining stumps or decaying root systems on the downstream slope or toe area.

If inappropriate vegetation is observed, the inspector should:

- Photograph the area and record the findings.
- Note the size, location, and extent of the inappropriate vegetation, or inadequate vegetation.
- Recommend that corrective action is taken to repair inadequate vegetation, or to eliminate inappropriate vegetation, and that measures are taken to prevent the future growth of undesirable vegetation.
- Consult a qualified dam safety professional if help is needed.

5.8 DEBRIS

The collection of debris on and around the dam is usually not an immediate danger to the integrity of the dam. However, unattended debris can lead to serious problems. The buildup of brush and logs on the dam can obscure the upstream slope and can prevent adequate visual inspection. Debris can accelerate the process of degradation of the riprap or other slope protection by impact from wave action.

Figure 5-29 Excessive debris around the riser trash rack can reduce discharge capacity and increase water levels.

Figure 5-30 A beaver has blocked the spillway on this dam.

Debris can clog or block spillway and outlet systems, resulting in potential dam overtopping hazards. Woody debris can become waterlogged and sink, possibly blocking an outlet works, inlet, or spillway inlets. Floating debris can also clog trash racks on spillways with riser conduits. The blocking of these inlet structures can cause overtopping of the dam in the event of a flood.

Certain animals, such as beavers, can contribute to the accumulation of debris in and around the dam. Removal of debris is usually a relatively easy task.

If the inspector finds debris in and around the dam, he/she should:

- Determine the cause of the debris, and, photograph, record, and report observations.
- Recommend that appropriate corrective action is taken to remove the debris, and that measures are taken to prevent the future accumulation of debris.

Figure 5-31 Telltale signs of a muskrat burrow.

5.9 BURROWING ANIMALS

Animal burrows can be dangerous to the structural integrity of the dam since they may weaken the embankment and can create pathways for seepage. Animals that can cause destruction to embankment dams include groundhogs (woodchucks), muskrats, and ground squirrels.

Burrowing animals make nests and passageways in soil, including many dam embankments. The animal passageways can lead to piping in the embankment soils when they connect the reservoir to the downstream slope or penetrate the dam's core. Shallow burrows or burrows that are confined to one side of the embankment may be less dangerous than these deep or connective passageways. If shallow burrows are so prevalent that they honeycomb an embankment, the integrity of the embankment is suspect. A qualified dam safety professional should be consulted for serious cases to determine how the deficiency might be corrected. If burrowing animals are present, the inspector should photograph the area and record his/her findings, and recommend that measures be taken before serious damage occurs to the dam. Eradication or removal is usually the recommended course of action. The local IDNR conservation officer should be contacted to obtain additional guidance on controlling animals on dams.

Figure 5-32 Rodent burrow.

Rodents such as the groundhog (woodchuck), muskrat, and beaver are attracted to dams and reservoirs, and can be quite dangerous to the structural integrity and proper performance of the embankment and spillway. Groundhog and muskrat burrows weaken the embankment and can serve as pathways for seepage. Beavers may plug the spillway and raise the pool level. Rodent control is essential in preserving a well-maintained dam.

Figure 5-33 Groundhogs can make extensive burrows in an embankment.

The groundhog is the largest member of the squirrel family. Occupied groundhog burrows are easily recognized in the spring due to the groundhog's habit of keeping them "cleaned out." Fresh dirt is generally found at the mouth of active burrows. Half-round mounds, paths leading from the den to nearby fields, and clawed or girdled trees and shrubs also help identify inhabited burrows and dens. When burrowing into an embankment, groundhogs stay above the phreatic surface (upper surface of seepage or saturation) to stay dry. The groundhog usually burrows into the embankment from the downstream slope; the burrow is rarely a single tunnel. It is usually forked, with more than one entrance and with several side passages or rooms from 1 to 12 feet long. Groundhogs can be controlled by using fumigants or by removal from the site. Fumigation is the most practical method of controlling groundhogs. Removal may be preferable around buildings or other high fire hazard areas. Groundhogs will be discouraged from inhabiting the embankment if the vegetal cover is kept mowed.

The muskrat is a stocky rodent with a broad head, short legs, small eyes, and rich dark brown fur. Muskrats are chiefly nocturnal. Muskrats can be found wherever there are marshes, swamps, ponds, lakes, and streams having calm or very slowly moving water with vegetation in the water and along the banks. Muskrats make their homes by burrowing into the banks of lakes and streams or by building "houses" of rushes and other plants. Their burrows begin from 6 to 18 inches below the water surface and penetrate the embankment on an upward slant. At distances up to 15 feet from the entrance, a dry chamber is hollowed out above the water level. Once a muskrat den is occupied, a rise in the water level will cause the muskrat to dig farther and higher to excavate a new dry chamber. Damage (and the potential for problems) is compounded where groundhogs or other burrowing animals construct their dens in the embankment opposite muskrat dens.

Figure 5-34 Telltale signs of a beaver.

Beaver will try to plug spillways with their cuttings. Typical signs of beaver at a dam are tooth-marked trees and stumps. Routinely removing the cuttings is one way to alleviate the problem. Another successful remedy is the placement of electrically charged wire or wires around the spillway inlet. Trapping beaver may be done by the owner during the appropriate season.

Crawfish, mice, and moles are also very common on earth embankments. These animals live in small burrows which generally do not pose a threat to dam safety. Crawfish dig vertical holes from the ground surface to a level below the groundwater surface, or phreatic surface, in the embankment. These holes are small and are usually vertical only, so they normally do not create the potential for lateral water seepage through the embankment. However, in some instances, their holes have been observed to intercept the phreatic surface on the downstream embankment slope, resulting in concentrated water seepage from the dam. In these cases, removal of the crawfish and repair of the embankment may be required.

During the visual inspection, the inspector should:

- Look for signs of burrowing animals and beavers.
- Photograph and record signs of animal presence and damage they have caused.
- Recommend that appropriate corrective action be taken to remove the animals from the dam and to repair the damage.

5.10 SEEPAGE

5.10.1 Overview

Every embankment dam has water passing through or under the embankment because all earth materials are porous. The passage of water through or under the embankment is known as seepage. Seepage quantities and rates increase as the depth of the water in the reservoir increases due to the greater pressure upstream of the embankment.

Seepage becomes a problem when embankment or foundation materials are moved by the water flow, or when excessive pressure builds up in the dam or its foundation. Problem seepage is often referred to as uncontrolled seepage. Excessive seepage and pressure can result in slides and embankment instability. Slides and other embankment problems are often a direct result of seepage that has saturated the embankment soils. Problem seepage is a serious concern and should be corrected before embankment structural damage occurs.

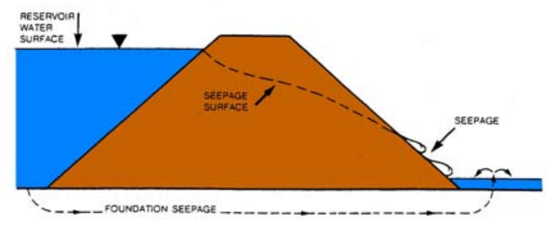


Figure 5-35 Seepage may occur through the embankment or the foundation.

5.10.2 Types and Location of Seepage

Seepage can emerge anywhere on the downstream face, beyond the toe, or on the downstream abutments at elevations below normal pool. Seepage may vary in appearance from a soft, wet area to a flowing spring. It may show up first as only an area where the vegetation is more lush and darker green. Downstream groin areas should always be inspected closely for signs of seepage. Seepage can also occur along the contact between the embankment and a conduit spillway, drain, or other appurtenance. Slides in the embankment or an abutment may be the result of seepage causing soil saturation or pressures in the soil pores.

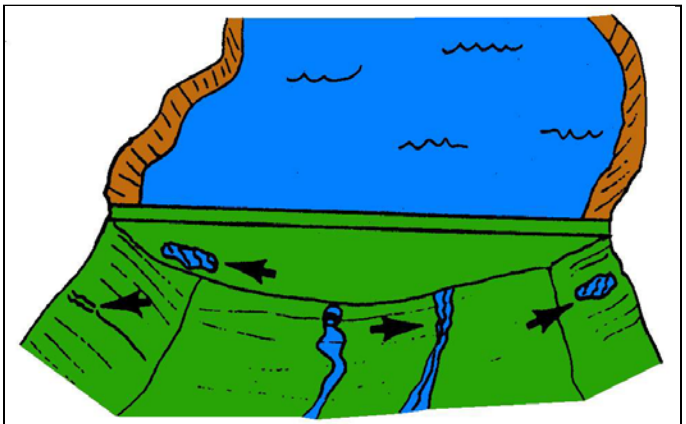


Figure 5-36 Common areas where seepage is observed.

Some water will seep from the reservoir through the foundation at most dams. Where it is not intercepted by a subsurface drain, the seepage will emerge downstream from or at the toe of the embankment. If the seepage forces are large enough, soil will be eroded from the foundation and be deposited in the shape of a cone around the outlet. If these “boils” appear, professional advice should be sought immediately. Seepage flow which is muddy and carrying soil particles is evidence of piping, and complete failure could occur within hours if it is serious. Piping can occur along a spillway and other conduits through the embankment, and these areas should be closely inspected. Sinkholes that develop on the embankment may be signs that piping has begun, and could be followed by a whirlpool in the lake surface and then a rapid and complete failure of the dam. Emergency procedures, including downstream evacuation, must be implemented if this condition is noted.

Figure 5-37 Piping through the foundation; notice the turbid discharge.

A slow continuous drop in the normal lake level could be the result of evaporation or drawdown due to maintenance of minimum releases. However, an inexplicable continuous recession in pool level, or especially, a sudden drop in water level is usually an indication that serious problems exist and immediate attention is required. The entire embankment, the appurtenances, and the area downstream should be inspected for signs of increased seepage or flowing water. This condition may indicate a serious problem and will require frequent, close monitoring and the assistance of qualified professionals.

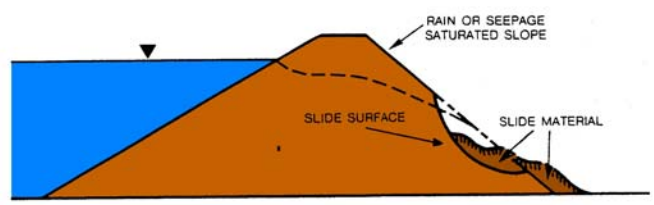


Figure 5-38 Uncontrolled seepage may result in slides and slope failure.

Uncontrolled seepage is a major cause of embankment dam failure. Seepage problems can be divided into two categories based on the type of problem it causes: stability problems, and piping problems. Seepage causes stability problems when high water pressure and saturation in the embankments and foundations cause the earth materials to lose strength. If uncontrolled seepage emerges on the lower downstream slope, the seepage will usually cause sloughing or massive slides. If seepage is concentrated through materials such as sands or cohesionless silts, the force of the flowing water can start to remove material at the exit point, and cause progressive erosion known as piping.

Piping usually starts at or near the downstream toe with the removal of the soil material at the seepage exit, or outlet. A sand boil may develop at the seepage outlet if the material being eroded is coarse silt or sand. However, not all piping creates sand boils. Sand boils may not occur when concentrated seepage occurs through an embankment, along the groins, or in contact with concrete structures. Soil erosion continues upstream, eroding a void, or pipe, through which the water flows.

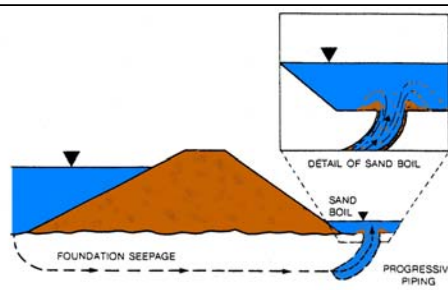


Figure 5-39 Sketch of progressive piping.

Erosion usually continues until the pipe extends all the way to the reservoir or other source of water. Severe piping problems can also occur when seepage moves embankment material into voids in rock foundations or rock fill portions of the dam.

Figure 5-40 Piping with clear discharge may indicate that no additional soil is being removed from the foundation.

It can be difficult to determine the source of seepage, since the exit may be the only visible condition observed. The seepage pipe shown in Figure 5-40 was observed a few feet below the toe of an earth embankment, and it was not clear whether the water was flowing through the embankment or under it. No sand or other soil was being carried by the seeping water, and the reservoir level was slowly getting lower, so the pipe was probably already formed. Seepage may originate in the bottom of the reservoir, upstream of the embankment, and travel through porous soil strata in the foundation of the dam.


Figure 5-41 This seepage has produced iron oxide stains.

Some seepage is difficult to detect since nothing is visible until the embankment starts to collapse, or until a vortex appears in the reservoir. A vortex is a rotational lake surface disturbance which could appear if water is rapidly conveyed through a seep or pipe. Formation of a vortex associated with a significant seep or piping through an embankment indicates a serious problem which requires immediate professional assistance.


Figure 5-42 Excessive seepage near embankment toe.

Seepage varies considerably in appearance and location. Seepage may appear as a wet area, as a flowing spring, or as a sand boil as described above. Vegetation is an excellent indicator of seepage; areas with water-loving vegetation, such as cattails, reeds, and mosses, should be checked for seepage. Also, areas where the normal vegetation appears to be greener or more lush than surrounding areas should be checked for seepage. Viewing the


Figure 5-43 Seepage along the spillway in this dam has resulted in piping and a serious leak.

downstream slope from a distance is sometimes helpful in detecting subtle changes in vegetation. A distinct line of vegetation probably indicates the intersection of the seepage line with the slope.

The contacts between the downstream slope and the abutments (or groins) are especially prone to seepage because the embankment fill near the abutments is often less dense than other parts of the embankment, and therefore less watertight. The embankment fill near the abutments is less dense because compaction is difficult along the embankment and abutment interface. Also, improperly sealed porous abutment rock can introduce abutment seepage into and along the embankment. Seepage in the groins may be groundwater from the abutments or valley walls, and not seepage from the reservoir. Seepage which exhibits an orange color or oily surface sheen typically indicates the presence of dissolved iron in the water. This is a common condition of groundwater that has been in contact with iron-bearing soils. The orange coloration is from iron oxide which develops after the groundwater is exposed to the air, causing the dissolved iron to oxidize (rust) and settle out of the water. The orange coloration is from deposits of iron oxide on the ground, and is not orange water.

The embankment toe is also prone to seepage, especially at the contact with the existing ground. This area has the greatest amount water pressure and is most likely to develop seeps. Seepage often occurs along the embankment-to-foundation interface. When seepage occurs at the toe of an embankment, a slide usually results. Figure 5-42 shows seepage accumulating at the toe of an embankment dam. Saturated embankment toes can cause catastrophic slope failures. Proper treatment of the foundation is crucial during the embankment construction to minimize and control seepage.


Figure 5-44 Seepage under this spillway conduit has caused piping, allowing a significant leak through conduit deficiencies.

Difficulties with soil compaction around conveyance structures like outlet works, spillway conduits, vertical walls, or penstocks make these areas more susceptible to uncontrolled seepage problems. Seepage exiting from around conveyance structures is particularly alarming because it may also indicate that there is a crack or opening in the structure that is allowing reservoir water under pressure into the embankment.

Rapid erosion and an eventual breaching of the dam can result from seepage around conduits. Figure 5-43 shows serious piping along a spillway conduit. This type of seepage is excessive and will continue to erode the soils around the conduit.

Figure 5-45 Seepage along this spillway conduit has caused piping, sinkholes, and eventual erosion of all the soil over the conduit.

Seepage along and under spillway conduits can find its way into the conduits, eventually eroding and deteriorating the conduit itself, as well as removing soil and bedding material from under the conduit. The conduit may settle or collapse if sufficient soil is piped out from under the structure. This type of seepage can be best observed when reservoir levels are below the spillway crest. In this situation, water will typically be coming out of the spillway conduit but will not be entering it from the inlet of the spillway in the reservoir. Many times sediment, or deposited soils, will be visible within or at the outlet of the conduit. High reservoir water levels will aggravate this condition.

Figure 5-46 Seepage caused by tree roots through the embankment.

Another usual symptom of seepage and piping along the conduit is settlement and depressions above the conduit, particularly within the conduit trench. Again, this is the result of the removal of soil from around the conduit, allowing it to be replaced by surface soils which fall into the voids created by the piping condition.

Seepage can be caused by deep-rooted vegetation on embankments, such as trees. Tree roots can penetrate the embankment and create passageways for water. Seepage along roots systems will usually start off at a very slow rate and get progressively greater with time. This is another example of the importance of early detection of seeps. As discussed earlier in this chapter, uprooted trees can also cause seepage problems.

Seepage from rock cuts on the abutments or the floor of the dam can create a number of potentially unsafe conditions. The inspector should evaluate the rate of seepage, correspondence of seepage rates to reservoir level, staining, and turbidity of seepage to fully understand the problem. Seepage can create excess hydrostatic pressure, weaken the overall strength of the abutment or foundation, and produce increasingly large channels for water flow. Openings can enlarge sufficiently to cause abutment or foundation movement or collapse. Stains from seepage water indicate solutioning of minerals which may reduce the shearing strength of the rock materials and cause rock consolidation. The inspector should take samples of the seepage so that the minerals can be identified. The inspector should also check the geologic data for evidence of deposits of limestone or other rock especially subject to solutioning that may underlie competent rock. Turbid flow indicates that internal erosion or piping is occurring. The inspector should check the construction records to see if rock walls and slopes were grouted to control seepage. If grouting was not done in the past, this procedure may control the seepage. If prior grouting proved inadequate to prevent or control seepage, a qualified dam safety professional should examine possible causes and sources for the seepage and evaluate corrective actions.

Figure 5-47 Typical photograph of seepage accumulating in low areas.

Seepage problems usually accelerate exponentially after they begin, and typically get worse with time. The location, quantity, and flow rate of all seepage should be monitored at the exit points. Recent precipitation events that may affect the appearance and quantity of seepage should also be noted and recorded.

During the visual inspection, the inspector should:

- Carefully inspect all of the areas that are prone to seepage, including downstream embankment slopes, embankment toe, the area downstream of the toe, the embankment groins, and along the spillways.
- Look for all visual signs of seepage, including: wet areas, excessive vegetative growth, lush green grass, lowered reservoir pool levels, piping, boils, sinkholes, flow into the discharge conduit from the soil, flow out of the discharge conduit into the soil, and embankment slides.

If seepage is observed, the inspector should:

- Record the findings and photograph the area. Notes, sketches, and photographs are useful in documenting and evaluating seepage problems.
- Determine the extent, severity, and cause of the seepage. Measure and photograph any damage caused by the seepage so that its progression can be monitored if necessary.
- If seepage is observed, it should always be monitored and measured on a regular and frequent basis.
- The seepage should be checked for turbidity which indicates the presence of soil in the water.
- Recommend that corrective action be taken to control the seepage.
- Recommend that corrective action is taken to repair the areas damaged by seepage and that measures are taken to prevent more serious problems.
- If extensive embankment excavation is required, the reservoir level may need to

be lowered.
- Consult a qualified dam safety professional if necessary.

5.10.3 Monitoring Seepage

Seepage may be or may become a serious problem and should always be monitored, regardless of the location, extent, or type of seepage present. Different monitoring procedures are available depending on the type of condition. Part 2 of the Dam Inspection Manual describes instrumentation and monitoring of seepage in more detail.

The amount of seepage usually correlates with the level of the reservoir. Generally, as the level of the reservoir rises, the seepage flow rate increases. Any changes in seepage flow rate which deviate from past seepage history are cause for concern. Recording seepage flow rates and reservoir levels will help assess a dam's seepage problems.

Seepage may discharge from the embankment at a distinct point, at several distinct points, or over a broad area. Seepage discharge at distinct points can often be readily measured. The rate of flow (gal/min, or gal/s) can be estimated and used for future comparison. The flow rate can be converted to quantity of flow over a specific period of time, such as a day, a week, or a month. These estimates can be used to determine if the embankment and/or foundation may be damaged from the flows.

Seepage on the embankment slopes, groins, or at the toe may occur over a relatively large area which does not lend itself to measurement in terms of flow rate and quantity. In these cases, the seepage may be best measured as width or length of affected area, or as a qualitative judgment of the physical appearance of the seepage area. Alternately, a dike, pipe, or other conveyance device could be installed on the embankment to concentrate the flows to facilitate measurement. If a slide has developed as is often the case, the dimensions of the slide can be measured and recorded. General descriptions of the amount of flow and degree of vegetative growth are also helpful. For example, seepage can be described as being visibly flowing on the ground surface, or as a wet spot with standing water puddles. If all of the seepage flows to a downstream channel or ditch, the flow rate may be estimated at that point.

If a **sand boil** or **piping exit** is observed, the inspector should:

- Photograph and record the size and depth of the exit, or outlet opening.
- Photograph and record the size of the deposition cone, if it is a sand boil.
- Monitor the flow rate, if possible. The flow rate may be difficult to ascertain if the pipe outlet or sand boil is under water.
- Probe the outlet opening for depth and soil composition and consistency.
- Make sure that all sand boils are evaluated by a qualified dam safety professional so that appropriate remedial action can be taken.

Sometimes placing sandbags around the boil to increase the depth of water (head) over the boil will prevent continued growth of the boil. Another temporary repair is to place a graded filter over the outlet opening to prevent additional soil from being carried out of the pipe or boil.

In some cases, a **dye test** (using an approved, environmentally safe dye) can be used to determine whether or not the reservoir is the source of seepage. A dye test is not a routine procedure, is not always applicable, and may be very difficult to administer. The approximate origin of the seep must be located in the reservoir so that the dye can be placed in the water near the area where water is entering the seep. The length of time it takes to conduct a test may vary since the dye may take different amounts of time to penetrate the embankment or foundation. In most cases, records of seepage volumes that correlate with pool elevations are needed to show that seepage comes from the reservoir.

Weirs, flumes and dikes can be installed to measure seepage, especially seepage exiting from the embankment or foundation at random point sources. When properly calibrated and kept free of silt and vegetation, weirs and flumes can measure seepage accurately. These devices can also be used downstream of general seepage areas where the water flows into a ditch or channel. Weirs and flumes that are silted-in may indicate that the embankment or foundation material is being piped out of the dam, or sediment from surrounding surface runoff erosion is collecting in the structure. If weirs and flumes become silted-in, the situation should be carefully evaluated to determine the cause of the siltation. Dikes can be installed across a channel or ditch with a pipe installed to measure flow also.

Many **toe drains** have collector pipes that discharge the embankment and foundation seepage at accessible locations. Before conducting a visual inspection of an embankment dam that has toe drains, the inspector should review the site plan to determine the location of the toe drains and outfalls. Previous data on both the reservoir level and flow rate from the drain(s) should be reviewed. Data on drain flow must be looked at in conjunction with reservoir-level data. Correlating the reservoir level with the drain flow can help to determine if there is a problem. If a drain flow is observed that is atypical for the given reservoir level, more investigation is essential.

Figure 5-48 Collector pipes (beside spillway conduit) can be used to help monitor seepage through the embankment.

During the visual inspection, the inspector should:

- Locate each toe drain outfall.
- Measure the flow. A simple method of measuring the flow from a toe drain outfall is to catch the flow from the pipe in a container of known volume and to time how long it takes to fill the container. The flow rate is usually recorded in gallons per minute.
- Compare the amount of flow with the amount of flow anticipated for the current reservoir level based on previous readings.

A drain that has no flow at all could indicate that there is no seepage in the area of the dam serviced by the drain, or that the drain is plugged or blocked. If the drain has never functioned, it could mean that the drain was designed or installed incorrectly. If the drain used to flow but has now stopped flowing, it may have become plugged. A plugged drain can be a serious problem because seepage may begin to exit downslope, or may contribute to internal pressure and instability. If possible, blocked drains should be cleaned so that the controlled release of seepage may be restored.

Decreasing amounts of flow from a drain for the same reservoir level may indicate that the drain is becoming blocked. Conversely, a sudden increase in drain flow may indicate that the core is becoming less watertight, possibly as the result of transverse cracking.

If **relief wells** have been installed at a dam, they may help to monitor seepage also. Before conducting a visual inspection of an embankment dam that has relief wells, the inspector should:

- Review the site plan to determine the location of the wells.
- Review previous data on both the reservoir level and well flow. Data on well flow must be evaluated in conjunction with reservoir-level data. Knowing how the reservoir level affects the well flow can help determine if there is a problem.
- If a well flow seems to be atypical for the given reservoir level, more investigation is essential.

During the visual inspection, the inspector should:

- Locate each relief well.
- Visually check whether or not water flow is occurring.
- Compare the amount of well flow measured with the amount of flow anticipated for the current reservoir level based on previous readings.

If no water is flowing from the relief well, determine if a flow should be present based on the assessment of the previous readings and the current reservoir level. If water is flowing, measure the rate of flow. The rate of flow can be measured either at the well or at the collector pipe discharge. Weirs, flumes, or a bucket and stopwatch can be used to measure the flow rate.

If the well flow is less than the amount anticipated, the well screens or filters may have become clogged. If it is suspected that the well is not functioning properly because it is clogged, cleaning should be recommended.

If the well flow is greater than the amount anticipated, there may be excessive seepage. Make sure that the flow rate and reservoir level are accurately recorded. The inspector should also note that there has been a change from the well-flow trends previously observed.

In addition to measuring the flow rate of seepage, the inspector should evaluate the clarity of the seepage. **Turbidity** is cloudy seepage, which indicates that soil particles are suspended in the water. Turbidity indicates that the water passing through the embankment or foundation is carrying soil with it. Turbidity is cause for extreme concern. Each time seepage is measured or inspected, the clarity of the seepage should also be evaluated for change.

A good way of detecting a change in turbidity is to collect a number of water samples as follows:

(1) Collect a sample of the water in a quart jar. Date the jar and note the level of clarity. Store the jar in a safe location.
(2) Repeat step I each time seepage flow is measured until several samples have been collected.
(3) Each time a sample is collected, shake up each jar and visually compare the new sample with the samples collected previously. Look for changes in the cloudiness of the samples. Also note the amount of sediment that accumulates in the bottom of the jars as suspended material settles out.

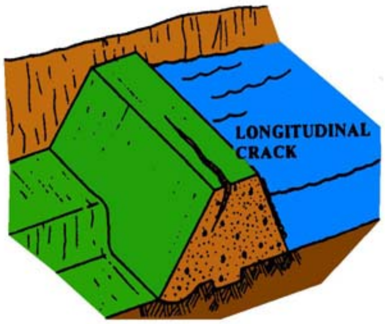
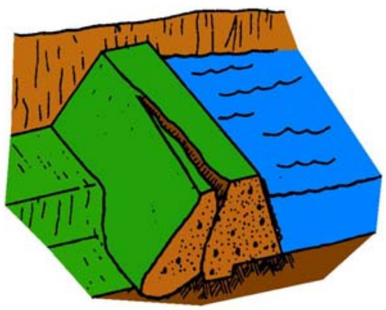
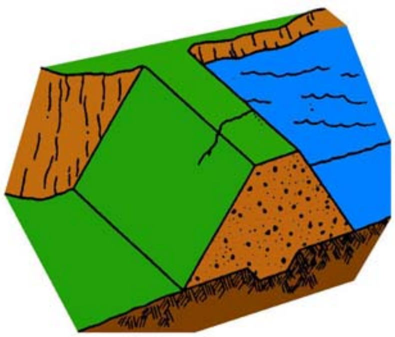
If seepage is clear, but it is suspected that it contains dissolved material from the foundation (because, for instance, seepage has increased without any signs of turbidity), it may be necessary to perform water quality testing.

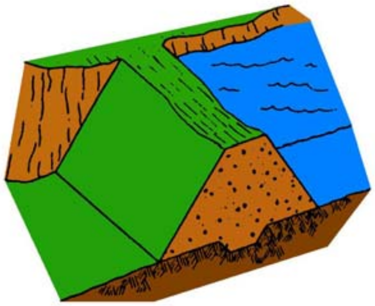
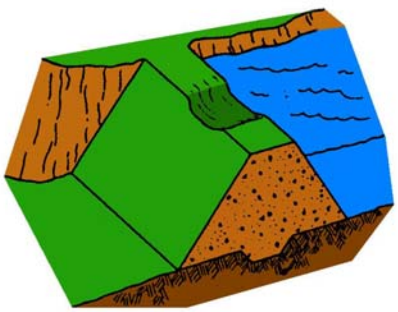
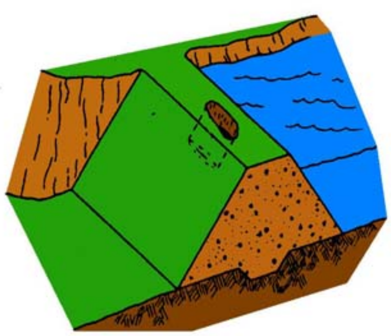
The rate and turbidity of seepage flow should be recorded during each visual inspection. If seepage problems are suspected, then the frequency of inspections should be determined by a qualified dam safety professional. If seepage problems continue to occur, further testing should be conducted by a qualified dam safety professional. Seepage problems are a serious concern, and uncontrolled seepage is a major cause of embankment dam failure.

Piezometers or monitoring wells can be installed in the embankment to monitor the level of water in the soil. These wells can be useful for detecting changes in seepage within the embankment, and for detecting excessive seepage zones if they are installed at intervals across the entire length of the embankment. The level to which water will rise in a piezometer is equal to the pressure at that location. If there is no seepage present, there will be no water observed in the piezometer well. They can also be installed in the foundation and abutments to monitor groundwater. Installation of piezometers requires a qualified geotechnical contractor. Piezometer monitoring is generally not as effective as seepage monitoring since piezometers only measure conditions at the exact location at which they are installed.

5.11 Dam Inspection Sketches

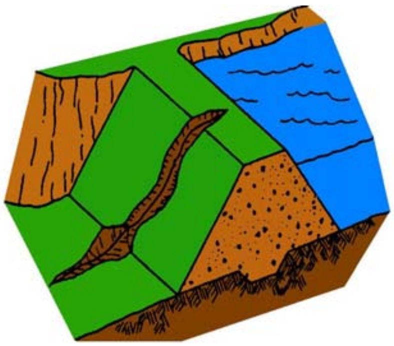
The following pages contain sketches of conditions that may be found on the embankment of the dam during a visual inspection. While most of the conditions on the following tables can be corrected by routine and periodic maintenance conducted by the owner, some of the conditions noted are of a nature that threaten the safety and integrity of the dam and require the attention of a qualified dam safety professional (if immediate emergency action is not required). Depending on the severity of the condition, the dam owner may need to take immediate action to prevent the condition from worsening, including contacting repair contractors, notifying local emergency authorities, and notifying downstream residents or occupants. A qualified dam safety professional is a person with specific expertise in the field of concern. For example, an engineer or geologist with geotechnical or geological experience may need to be consulted if a slope stability or soil issue exists. Or, an engineer with hydrologic and hydraulic experience will be required to determine spillway capacity.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
LONGITUDINAL CRACKING  	**Probable Cause:** 1. Uneven settlement between adjacent sections or zones within the embankment. 2. Foundation failure causing loss of support to embankment. **Harm**: 1. Creates local area of low strength within embankment. Could be the point of initiation of future structural movement, deformation, or failure. 2 Provides entrance point for surface run-off into embankment, allowing saturation of adjacent embankment area and possible lubrication which could lead to localized failure.	**Potential Action:** 1. Inspect crack and carefully record location, length, depth, width, alignment, and other pertinent physical features. Immediately stake out limits of cracking. Monitor frequently. 2. Engineer should determine cause of cracking and supervise steps necessary to reduce danger of dam and correct condition. 3. Effectively seal the cracks at the crest's surface to prevent infiltration by surface water. 4. Continue to routinely monitor crest for evidence of further cracking. *Qualified Dam Safety Professional Required*
VERTICAL DISPLACEMENT 	**Probable Cause:** 1. Vertical movement between adjacent sections of the embankment. 2. Structural deformation or failure caused by structural stress or instability, or by failure of the foundation. **Harm**: 1. Provides local area of low strength within embankment which could cause future movement. 2. Leads to structural instability or failure. 3. Provides entrance point for surface water that could further lubricate failure plane. 4. Reduces available embankment cross section.	**Potential Action:** 1. Carefully inspect displacement and record its location, vertical and horizontal displacement, length, and other physical features. Immediately stake out limits of cracking. 2. Engineer should determine cause of displacement and supervise all steps necessary to reduce danger to dam and correct condition. 3. Excavate area to the bottom of the displacement. Backfill excavation, using competent material and correct construction techniques, under supervision of engineer. 4. Continue to monitor areas routinely for evidence of future cracking or movement. *Qualified Dam Safety Professional Required*
TRANSVERSE CRACKING 	**Probable Cause:** 1. Uneven movement between adjacent segments of the embankment. 2. Deformation caused by structural stress or instability. **Harm**: 1. Can provide a path for seepage through the embankment cross section. 2. Provides local area of low strength within embankment. Future structural movement, deformation, or failure could begin at this point. 3. Provides entrance point for surface run-off to enter embankment.	**Potential Action:** 1. Inspect crack and carefully record crack location, length, depth, width, and other pertinent physical features. Stake out limits of cracking. 2. Engineer should determine cause of cracking and supervise all steps necessary to reduce danger to dam and correct condition. 3. Excavate crest along crack to a point below the bottom of the crack. Then backfill excavation using competent material and correct construction techniques. This will seal the crack against seepage and surface run-off. This should be supervised by engineer. 4. Continue to monitor crest routinely for evidence of future cracking. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
CREST ALIGNMENT 	**Probable Cause**: 1. Movement between adjacent portions of the structure. 2. Uneven deflection of dam under loading by reservoir. 3. Structural deformation or failure near area of misalignment. **Harm**: 1. Area of misalignment is usually accompanied by low area in crest which reduces free board. 2. Can produce local areas of low embankment strength which may lead to failure.	**Potential Action:** 1. Establish monuments across crest to determine exact amount, location, and extent of misalignment. 2. Engineer should determine cause of misalignment and supervise all steps necessary to reduce threat to dam and correct condition. 3. Monitor crest monuments on a schedule basis following remedial action to detect possible future movement. *Qualified Dam Safety Professional Required*
LOW AREA IN CREST OF DAM 	**Probable Cause**: 1. Excessive settlement in the embankment or foundation directly beneath the low area in the crest. 2. Internal erosion of embankment material. 3. Foundation spreading toward upstream and/or downstream direction. 4. Prolonged wind erosion of crest area. 5. Improper final grading following construction. **Harm**: Reduces freeboard available to pass flood flows safely through spillway.	**Potential Action:** 1. Establish monuments along length of crest to determine exact amount, location, and extent of settlement in crest. 2. Engineer should determine cause of low area and supervise all steps necessary to reduce possible threat to the dam and correct condition. 3. Re-establish uniform crest elevation over crest length by placing fil1 in low area using proper construction techniques. This should be supervised by engineer. 4. Re-establish monuments across crest of dam and monitor monuments on a routine basis to detect possible future settlement. *Qualified Dam Safety Professional Required*
SINKHOLE IN CREST 	**Probable Cause**: 1. Rodent activity. 2. Hole in outlet conduit is causing erosion of embankment material. 3. Internal erosion or piping of embankment material by seepage. 4. Breakdown of dispersive clays within embankment by seepage waters. **Harm**: 1. Void within dam could cause localized caving, sloughing, instability, or reduced embankment cross section. 2. Entrance point for surface water.	**Potential Action**: 1. Carefully inspect and record location and physical characteristics (depth, width, length) of sinkhole. 2. Engineer should determine cause of sinkhole and supervise al1 steps necessary to reduce threat to dam and correct condition. 3. Excavate sinkhole, slope sides of excavation, and backfill hole with competent material using proper construction techniques. This should be supervised by an engineer. *Qualified Dam Safety Professional Required*

PROBLEMS | **CAUSES & HARM DONE** | **ACTION REQUIRED**

GULLY ON CREST



Probable Cause:

1. Poor grading and improper drainage of crest. Improper drainage causes surface run-off to collect and drain off crest at low point in upstream or downstream shoulder.
2. Inadequate spillway capacity which has caused dam to overtop.

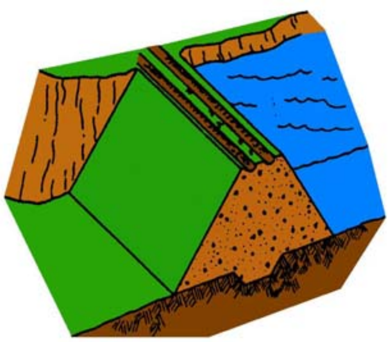
Harm:

1. Can reduce available freeboard.
2. Reduces cross-sectional area of dam.
3. Inhibits access to all parts of the crest and dam.

Potential Action:

1. Restore freeboard to dam by adding fill material in low area, using proper construction techniques.
2. Re-grade crest to provide proper drainage of surface run-off.
3. If gully was caused by over-topping, provide adequate spillway which meets current design standards. This should be done by engineer.
4. Re-establish protective cover.

RUTS ALONG CREST



Probable Cause:

Heavy vehicular traffic without adequate or proper maintenance or proper crest surfacing.

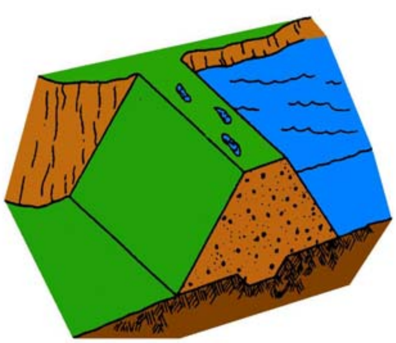
Harm:

1. Inhibits easy access to all parts of crest.
2. Allows continued development of rutting.
3. Allows standing water to collect and saturate crest of dam.
4. Operating and maintenance vehicles can get stuck.

Potential Action:

1. Drain standing water from ruts.
2. Re-grade and re-compact crest to restore integrity and provide proper drainage toward upstream slope.
3. Provide gravel or road base material to accommodate traffic.
4. Perform periodic maintenance and re-grading to prevent reformation of ruts.

PUDDLING ON CREST; POOR DRAINAGE



Probable Cause:

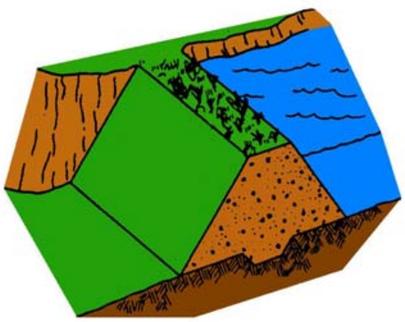
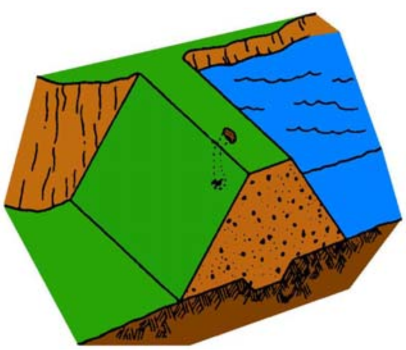
1. Poor grading and improper drainage of crest.
2. Localized consolidation or settlement on crest allows puddles to develop.

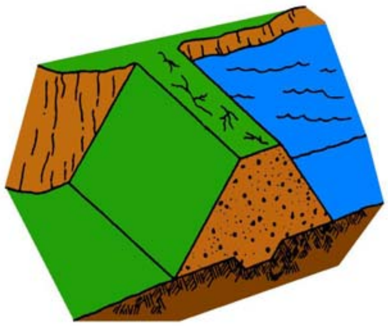
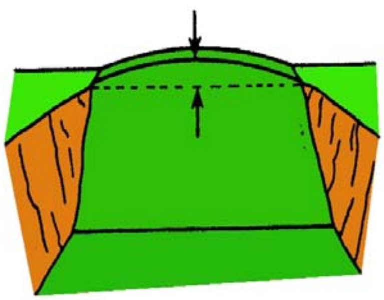
Harm:

1. Causes localized saturation of the crest.
2. Inhibits access to all portions of the dam and crest.
3. Becomes progressively worse if not corrected.

Potential Action:

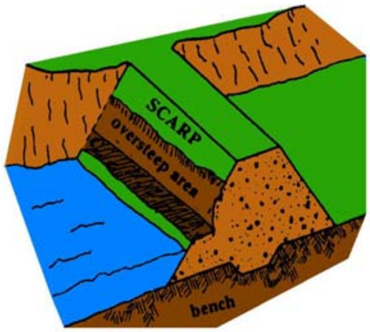
1. Drain standing water from puddles.
2. Re-grade and re-compact crest to restore integrity and provide proper drainage toward upstream slope.
3. Provide gravel or road base material to accommodate traffic.
4. Perform periodic maintenance and re-grading to prevent reformation of ruts.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
OBSCURING VEGETATION 	**Probable Cause**: Neglect of dam and lack of proper maintenance procedures. **Harm**: 1. Obscure large portions of the dam, preventing adequate, accurate visual inspection of all portions of the dam. Problems that threaten the integrity of the dam can develop and remain undetected until they progress to a point where the dam's safety is threatened. 2. Associated root systems develop and penetrate into the dam's cross section. When the vegetation dies, the decaying root systems can provide paths for seepage. This reduces the effective seepage path through the embankment and could lead to possible piping situations. 3. Prevents easy access to all portions of the dam for operation, maintenance, and inspection. 4. Provides habitat for rodents.	**Potential Action**: 1. Remove all detrimental growth from the dam. This would include removal of trees, bushes, brush, conifers, and growth other than grass. Grass should be encouraged on all segments of the dam to prevent erosion by surface run-off. Root systems should also be removed to the maximum practical extent. The void which results from removing the root system should be backfilled with competent, well-compacted material. 2. Future undesirable growth should be removed by cutting or spraying, as part of an annual maintenance program. 3. All cuttings or debris resulting from the vegetative removal should be immediately taken from the dam and properly disposed of outside the reservoir basin.
RODENT ACTIVITY ON CREST 	**Probable Cause**: Burrowing animals. **Harm**: 1. Entrance point for surface runoff to enter dam. Could saturate adjacent portions of the dam. 2. Especially dangerous if hole penetrates dam below phreatic line. During periods of high storage, seepage path through the dam would be greatly reduced and a piping situation could develop.	**Potential Action**: 1. Completely backfill the hold with competent, well compacted material. 2. Initiate a rodent control program to prevent the propagation of the burrowing animal population and to prevent future damage to the dam.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
DRYING CRACKS 	**Probable Cause**: Material on the crest of dam expands and contracts with alternate wetting and drying of weather cycles. Drying cracks are usually short, shallow, narrow, and numerous. **Harm**: Provides point of entrance for surface run-off and surface moisture, causing saturation of adjacent embankment areas. This saturation and subsequent drying of the dam could cause further cracking.	**Potential Action:** 1. Seal surface of cracks with a tight, impervious material. **or…** 2. Routinely grade crest to provide proper drainage and till cracks. **or…** 3. Cover crest with non-plastic (not clay) material to prevent large moisture content variations with respect to time. 4. Draw the reservoir down if safety of dam is threatened.
CREST CAMBER 	**Probable Cause**: Results from construction. Proportionally more fill is placed on crest in higher segments of the embankment during construction to compensate for anticipated settlement within the dam and foundation. **Harm**: None.	**Potential Action**: None.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

SCARPS, BENCHES, OVERSTEEP AREAS



Probable Cause:

Wave action, local settlement, or ice action cause soil and rock to erode and slide to the lower part of the slope forming a bench.

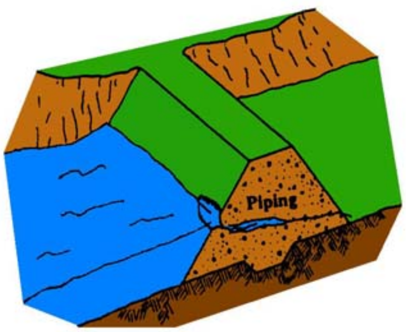
Harm:

This eroded area lessens the width and possible height of the embankment and could lead to increased seepage or overtopping of the dam.

Potential Action:

Determine exact cause of scarps. Do necessary earthwork, restore embankment to original slope, provide adequate protection (bedding and riprap).

SINKHOLE



Probable Cause:

The piping of embankment material or foundation material causes a sink hole. The cave-in of an eroded cavern can result in a sink hole. A small hole in the wall of an outlet pipe can develop a sink hole.

Harm:

This condition can empty a reservoir through a small hole in the wall of an outlet pipe or can lead to failure of a dam as soil pipes through the foundation or a pervious portion of the dam.

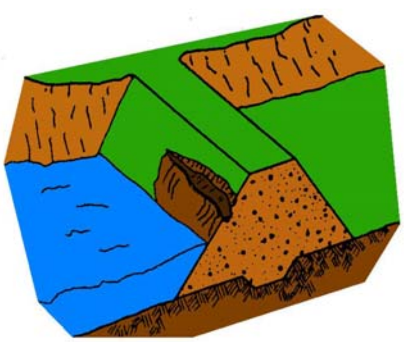
Potential Action:

Inspect other portions of the dam for seepage or additional sink holes. Identify exact cause of sink holes. Check seepage and leakage outflows for dirty water.

A qualified engineer should inspect the conditions and recommend further actions to be taken.

Qualified Dam Safety Professional Required

SLIDE, SLUMP, OR SLIP



Probable Cause:

Earth or rocks move down the slope along a slippage surface because they were on too steep a slope, or the foundation moves. Also, look for slides in reservoir basin.

Harm:

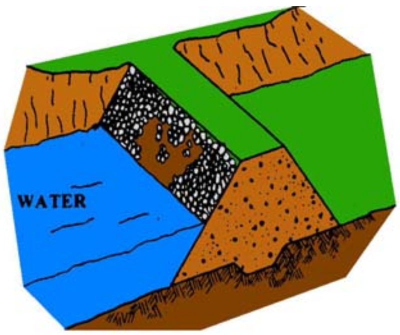
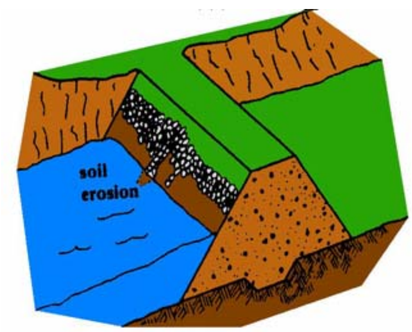
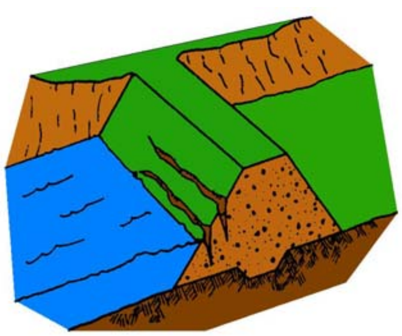
A series of slides can lead to obstruction of the outlet or failure of the dam.

Potential Action:

Evaluate extent of the slide. Monitor slide. Draw the reservoir level down if safety of dam is threatened.

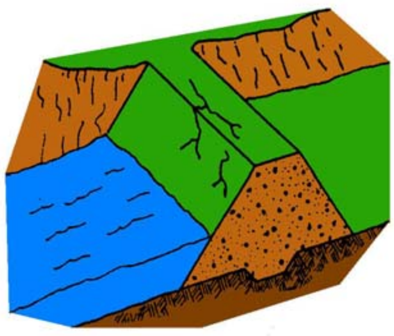
A qualified engineer should inspect the conditions and recommend further actions to be taken.

Qualified Dam Safety Professional Required

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
BROKEN DOWN, MISSING RIPRAP 	**Probable Cause**: Poor quality riprap has deteriorated. Wave action or ice action has displaced riprap. Round and similar sized rocks have rolled downhill. **Harm**: Wave action against these unprotected areas decreases embankment width.	**Potential Action**: Re-establish normal slope. Place bedding and competent riprap.
EROSION BEHIND POORLY GRADED RIPRAP 	**Probable Cause**: Similar-sized rocks allow waves to pass between them and erode small gravel particles and soil. **Harm**: Soil is eroded away from behind the riprap. This allows riprap to settle, providing less protection and decreased embankment width.	**Potential Action**: Re-establish effective slope protection. Place bedding material ENGINEER REQUIRED for design of gradation and size of rock for bed-ding and riprap. A qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
LARGE CRACKS ON SLOPE 	**Probable Cause**: A portion of the embankment has moved due to loss of strength, or the foundation may have moved, causing embankment movement. **Harm**: Can lead to failure of the dam.	**Potential Action**: Depending on the amount of embankment involved, draw reservoir level down. A qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

CRACKS DUE TO DRYING



Probable Cause:

The soil loses its moisture and shrinks, causing cracks.

Note:

Usually seen on crest and downstream slope mostly.

Harm:

Heavy rains can fill up cracks and cause small portions of embankment to move along internal slip surface.

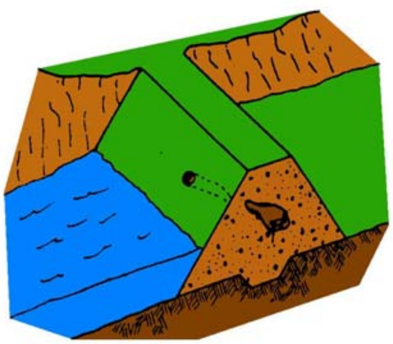
Potential Action:

1. Monitor cracks for increases in width, depth, or length.

2. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

BEAVER OR MUSKRAT ACTIVITY



Probable Cause:

Holes, tunnels, and caverns are caused by animal burrows. Certain habitats like cattail-type plants and trees close to the reservoir encourage these animals.

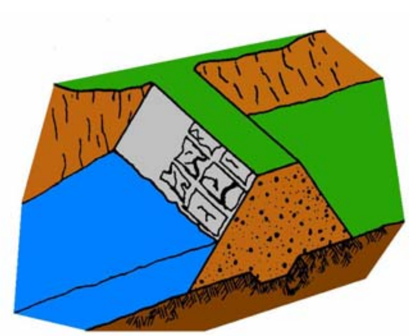
Harm:

If a tunnel exists through most of the dam, it can lead to failure of the dam.

Potential Action:

Remove rodents. Determine exact location of digging and extent of tunneling. Remove habitat. Repair damages.

CRACKED DETERIORATED CONCRETE FACE



Probable Cause:

Concrete deteriorated due to weathering. Joint filler deteriorated or displaced.

Harm:

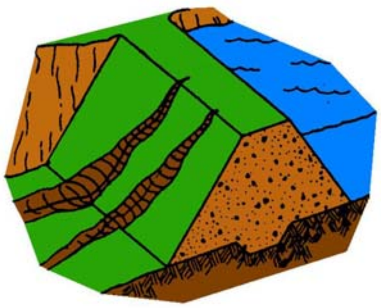
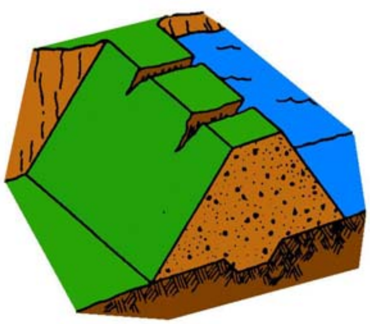
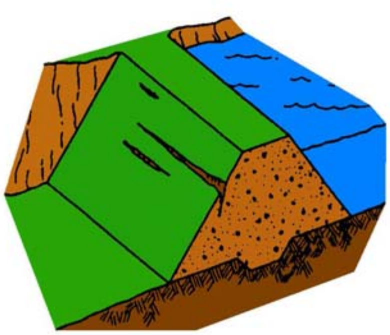
Soil is eroded behind the face and caverns can be formed. Unsupported sections of concrete crack. Ice action may displace concrete.

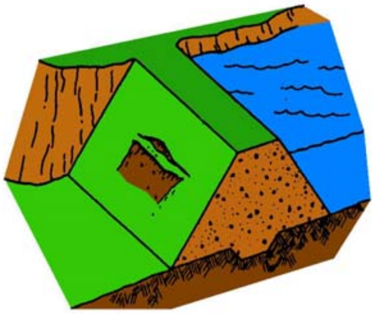
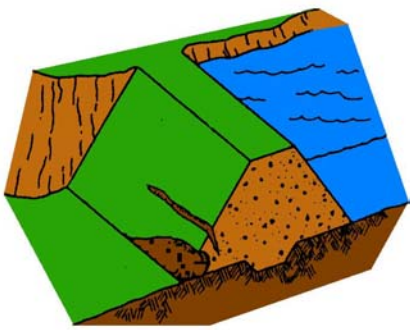
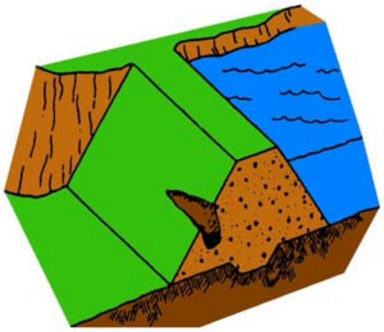
Potential Action:

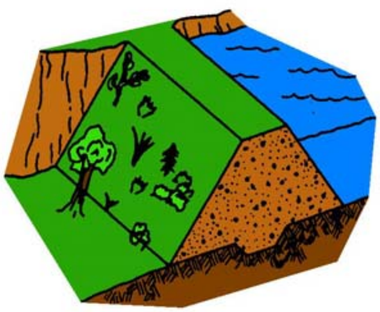
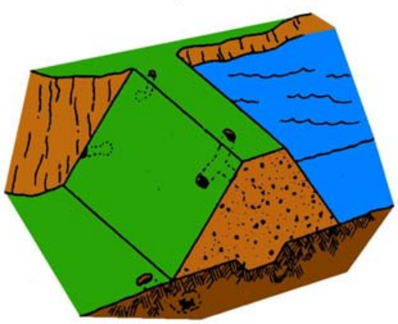
1. Determine cause. Either patch with grout or contact engineer for permanent repair method.

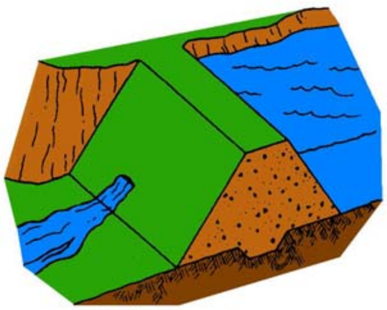
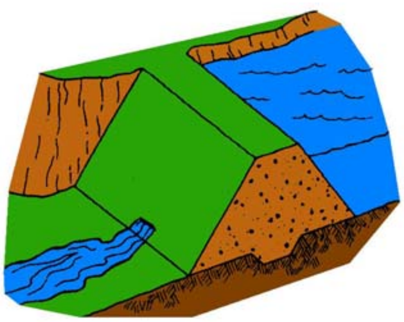
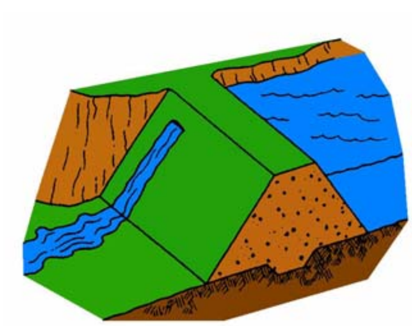
2. If damage is extensive, a qualified engineer should inspect the conditions and recommend further actions to be taken.

Qualified Dam Safety Professional Required

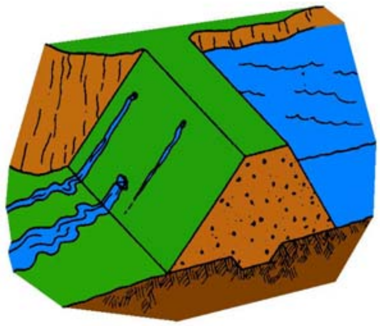
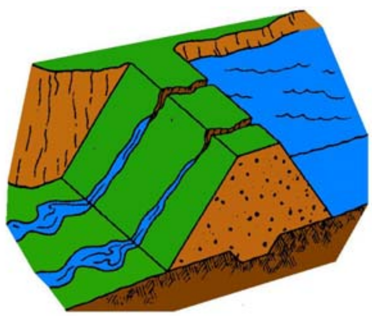
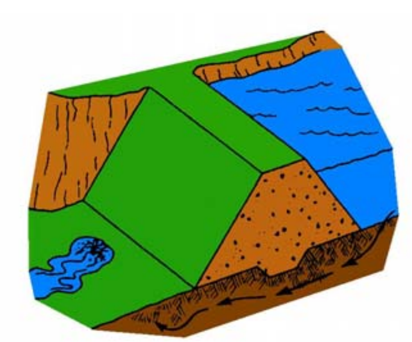
PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
EROSION 	**Probable Cause**: Water from intense rainstorms or snow-melt carries surface material down the slope, resulting in continuous troughs. **Harm**: If allowed to continue, erosion can lead to eventual deterioration of the downstream slope which can shorten the seepage path.	**Potential Action**: 1. The preferred method to protect eroded areas is rock or riprap. 2. Re-establishing protective grasses can be adequate if the problem is detected early.
TRANSVERSE CRACKING AFFECTING SLOPE 	**Probable Cause**: 1. Drying and shrinkage of surface material is most common. 2. Differential settlement of the embankment also leads to transverse cracking (e.g., center settles more than abutments). **Harm**: 1. Shrinkage cracks allow water to enter the embankment. This promotes saturation and increases freeze thaw action. 2. Settlement cracks can lead to seepage of reservoir water through the dam. 3. Can lead to uncontrolled breach.	**Potential Action**: 1. If necessary plug upstream end of crack to prevent flows from the reservoir. 2. A qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
LONGITUDINAL CRACKING ON SLOPE 	**Probable Cause**: 1. Drying and shrinkage of surface material. 2. Downstream movement or settlement of embankment. **Harm**: 1. Can be an early warning of a potential slide. 2. Shrinkage cracks allow water to enter the embankment and freezing will further crack the embankment. 3. Settlement or slide indicating loss of strength in embankment can lead to failure.	**Potential Action**: 1. If cracks are from drying, dress area with well-compacted material to keep surface water out and natural moisture in. 2. If cracks are extensive, a qualified engineer should inspect the conditions and recommend further actions to be taken. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
SLIDE/SLOUGH 	**Probable Cause**: 1. Lack of or loss of strength of embankment material. 2. Loss of strength can be attributed to infiltration of water into the embankment or loss of support by the foundation. **Harm**: Can lead to failure of the dam.	**Potential Action**: <u>HAZARDOUS!</u> 1. Measure extent and displacement of slide. 2. If continued movement is seen, begin lowering water level until movement stops. 3. Have a qualified engineer inspect the condition and recommend further action. *Qualified Dam Safety Professional Required*
SLUMP (LOCALIZED CONDITION0 	**Probable Cause**: Preceded by erosion undercutting a portion of the slope. Can also be found on relatively steep slopes. **Harm**: Can expose impervious zone to erosion.	**Potential Action**: 1. Inspect area for seepage. 2. Monitor for progressive failure. 3. Have a qualified engineer inspect the condition and recommend further action. *Qualified Dam Safety Professional Required*
SINK HOLE/COLLAPSE 	**Probable Cause**: Lack of adequate compaction; rodent hole below; piping through embankment or foundation. **Harm**: Shortens seepage path, can lead to washout of embankment and uncontrolled breach.	**Potential Action**: 1. Inspect for and immediately repair rodent holes. Control rodents to prevent future damage. 2. Have a qualified engineer inspect the condition and recommend further action. *Qualified Dam Safety Professional Required*

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
TREES/OBSCURING BRUSH 	**Probable Cause**: Natural vegetation in area. **Harm**: Large tree roots can create seepage paths. Brushes can obscure visual inspection and harbor rodents.	**Potential Action**: 1. Remove all large, deep-rooted trees and shrubs on or near the embankment. Properly backfill void. 2. Control all other vegetation on the embankment that obscures visual inspection.
RODENT ACTIVITY ON SLOPE 	**Probable Cause**: Overabundance of rodents. **Harm**: Reduces length of seepage path. Can lead to piping failure.	**Potential Action**: 1. Control rodents to prevent additional damage. 2. Backfill existing rodent holes.
LIVESTOCK/CATTLE TRAFFIC 	**Probable Cause**: Excessive travel by livestock especially harmful to slope when wet. **Harm**: Creates areas bare of erosion protection and causes erosion channels. Allows water to stand. Area susceptible to drying cracks.	**Potential Action**: 1. Fence livestock outside embankment area. 2. Repair erosion protection, i.e., riprap, grass.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
MUDDY WATER EXITING FROM A POINT SOURCE 	**Probable Cause**: 1. Water has created an open pathway, channel, or pipe through the dam. The water is eroding and carrying embankment material. 2. Large amounts of water have accumulated in the downstream slope. Water and embankment materials are exiting at one point. Surface agitation may be causing the muddy water. **Harm**: Continued flows can further erode embankment materials. This can lead to failure of the dam.	**Potential Action**: 1. Begin measuring outflow quantity and establishing whether water is getting muddier, staying the same, or clearing up. 2. If quantity of flow is increasing, the water level in the reservoir should be lowered until the flow stabilizes or stops. 3. A qualified engineer should inspect the condition and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
WATER EXITING FROM A POINT SOURCE 	**Probable Cause**: Water has created an open pathway or pipe through the dam. **Harm**: Continued flows can further erode embankment materials. This can lead to failure of the dam.	**Potential Action**: 1. Begin measuring outflow quantity. 2. If quantity of flow is increasing, the water level in the reservoir should be lowered until the flow stabilizes or stops. 3. A qualified engineer should inspect the condition and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
WATER EXITING FROM A POINT SOURCE HIGH ON THE EMBANKMENT 	**Probable Cause**: 1. Rodents, frost action, or poor construction have allowed water to create an open pathway or pipe through the embankment. **Harm**: 1. Continued flows can saturate portions of the embankment and lead to slides in the area. 2. Continued flows can further erode embankment materials and lead to failure of the dam.	**Potential Action**: 1. Begin measuring outflow quantity. 2. If quantity of flow is increasing, the water level in the reservoir needs to be lowered until the leak stops. 3. Search for opening on upstream side and plug it if possible. 4. A qualified engineer should immediately inspect the condition and recommend further action to be taken. *Qualified Dam Safety Professional Required*

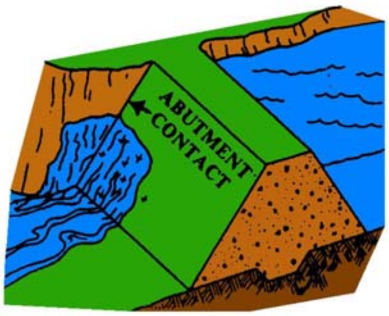
All problems are potentially hazardous.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED
WATER EXITING FROM RODENT HOLES 	**Probable Cause**: Diggings by the rodent have shortened the flow path. **Harm**: Continued flows can further erode embankment material and lead to failure of the dam.	**Potential Action**: 1. Locate any entrance points on the upstream slope and plug them. 2. If the quantity of flow is increasing, the water level in the reservoir needs to be lowered until the leak stops. 3. Bring a halt to the rodent activity. 4. A qualified engineer should inspect the condition and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
STREAM OF WATER EXITING THROUGH CRACKS NEAR THE CREST 	**Probable Cause**: 1. Severe drying has caused shrinkage of embankment material. 2. Settlement in the embankment or foundation is causing the transverse cracks. **Harm**: Flow through the crack can cause failure of the dam.	**Potential Action**: 1. Plug the upstream side of the crack to stop the flow. 2. The water level in the reservoir should be lowered until it is below the level of the cracks. 3. A qualified engineer should inspect the condition and recommend further actions to be taken. *Qualified Dam Safety Professional Required*
SEEPAGE WATER EXITING AS A BOIL IN THE FOUNDATION 	**Probable Cause**: Some portion of the foundation material is providing a flow path. This could be caused by a sand or gravel layer in the foundation. **Harm**: Increased flows can lead to erosion of the foundation and failure of the dam.	**Potential Action**: 1. Examine the boil for transportation of foundation materials. 2. If soil particles are moving downstream, sandbags or earth should be used to create a dike around the boil. The pressure created by the water level within the dike may control flow velocities and temporarily prevent further erosion. 3. If erosion is becoming greater, the reservoir level should be lowered. 4. A qualified engineer should inspect the condition and recommend further actions to be taken. *Qualified Dam Safety Professional Required*

All problems are potentially hazardous.

PROBLEMS | **CAUSES & HARM DONE** | **ACTION REQUIRED**

SEEPAGE EXITING AT ABUTMENT CONTACT



Probable Cause:

1. Water flowing through pathways in the abutment.
2. Water flowing through the embankment.

Harm:

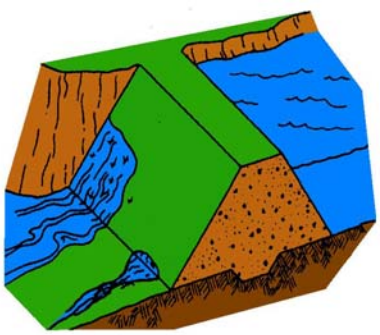
Can lead to erosion of embankment materials and failure of the dam.

Potential Action:

1. Investigate leakage area to determine quantity of flow and extent of saturation.
2. Inspect daily for developing slides.
3. Water level in reservoir may need to be lowered to assure the safety of the embankment.
4. A qualified engineer should inspect the conditions and recommend further actions to be taken.

Qualified Dam Safety Professional Required

LARGE AREA WET OR PRODUCING FLOW



Probable Cause:

A seepage path has developed through the abutment or embankment.

Harm:

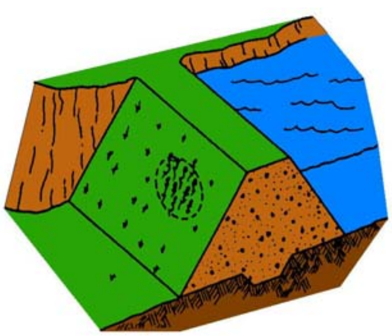
1. Increased flows could lead to erosion of embankment material and failure of the dam.
2. Saturation of the embankment can lead to local slides which could cause failure of the dam.

Potential Action:

1. Stake out the saturated area and monitor for growth or shrinking.
2. Measure any outflows as accurately as possible.
3. Reservoir level may need to be lowered if saturated areas increase in size at a fixed storage level or if flow increases.
4. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

MARKED CHANGED IN VEGETATION



Probable Cause:

1. Embankment materials are providing flow paths.
2. Natural seeding by wind.
3. Change in seed type during initial post construction seeding.

Harm:

Can indicate a saturated area.

Potential Action:

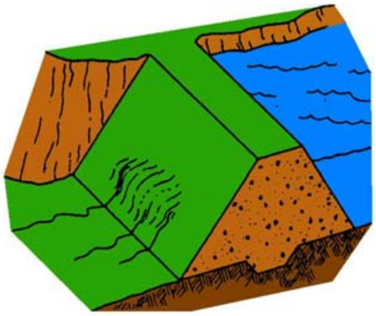
1. Use probe and shovel to establish if the materials in this area are wetter than in surrounding areas.
2. If area shows wetness when surrounding areas do not, a qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

All problems are potentially hazardous.

PROBLEMS	CAUSES & HARM DONE	ACTION REQUIRED

BULGE IN LARGE WET AREA



Probable Cause:

Downstream embankment materials have begun to move.

Harm:

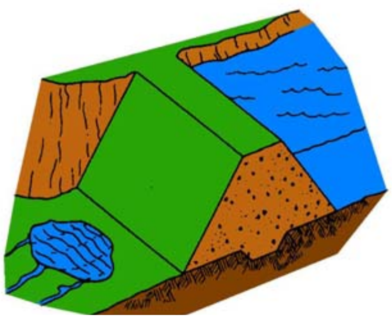
Failure of the embankment due to massive sliding can follow these initial movements.

Potential Action:

1. Compare embankment cross-section to the end of construction condition to see if observed condition may reflect end of construction.
2. Stake out affected area and accurately measure outflow.
3. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

TRAMPOLINE EFFECT IN LARGE SOGGY AREA



Probable Cause:

Water moving rapidly through the embankment or foundation is being controlled or contained by a well-established turf root system.

Harm:

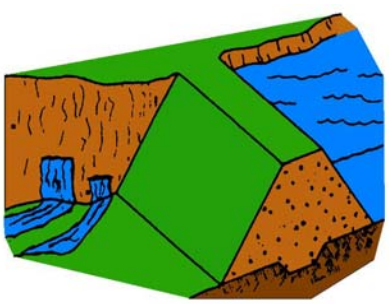
Condition indicates excessive seepage in the area. If control layer of turf is destroyed, rapid erosion of foundation materials could result in failure of the dam.

Potential Action:

1. Carefully inspect the area for outflow quantity and any transported materials.
2. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

LEAKAGE FROM ABUTMENTS BEYOND THE DAM



Probable Cause:

Water moving through cracks and fissures in the abutment materials.

Harm:

1. Can lead to rapid erosion of abutment and evacuation of the reservoir.
2. Can lead to massive slides near or downstream from the dam.

Potential Action:

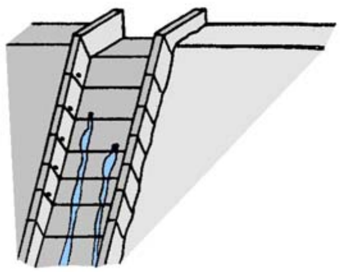
1. Carefully inspect the area to determine quantity of flow and amount of transported material.
2. A qualified engineer or geologist should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

All problems are potentially hazardous.

PROBLEMS | **CAUSES & HARM DONE** | **ACTION REQUIRED**

TOO MUCH LEAKAGE FROM SPILLWAY UNDER DRAINS



Probable Cause:

Drain or cutoff may have failed.

Harm:

1. Excessive flows under the spillway could lead to erosion of foundation material and collapse of portions of the spillway.

2. Uncontrolled flows could lead to loss of stored water.

Potential Action:

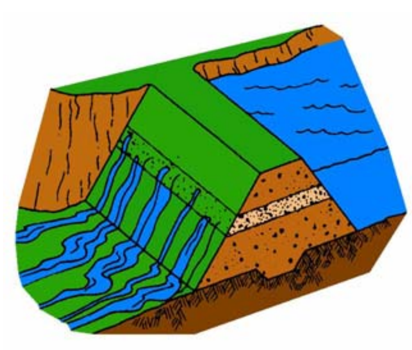
1. Immediately measure flow quantity and check flows for transported drain material.

2. If flows are accelerating at a fixed storage level, the reservoir level should be lowered until the flow stabilizes or stops.

3. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

WET AREA IN HORIZONTAL BAND



Probable Cause:

Frost layer or layer of sandy material in original construction.

Harm:

1. Wetting of areas below the area of excessive seepage can lead to localized instability of the embankment. (SLIDES)

2. Excessive flows can lead to accelerated erosion of embankment materials and failure of the dam.

Potential Action:

1. Determine as closely as possible the amount of flow being produced.

2. If flow increases, reservoir level should be reduced until flow stabilizes or stops.

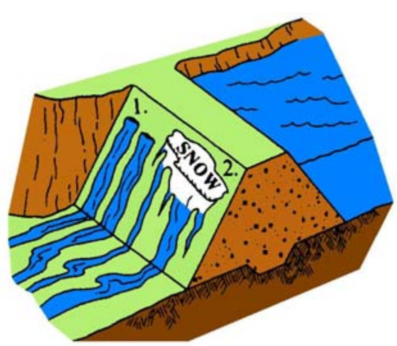
3. Stake out the exact area involved.

4. Using hand tools, try to identify the material allowing the flow.

5. A qualified engineer should inspect the condition and recommend further actions to be taken.

Qualified Dam Safety Professional Required

LARGE AREA SATURATED FROM ABOVE



Probable Cause:

1. Water flowing through the embankment.

2. Snowdrifts melting slowly during mild spring temperatures.

Harm:

Can lead to saturation of embankment materials and local or massive slides which could cause failure of the dam.

Potential Action:

1. Investigate saturated area to determine depth and extent of saturation.

2. Inspect daily for developing slides.

3. Water level in reservoir may need to be lowered to assure the safety of the embankment.

4. A qualified engineer should inspect the conditions and recommend further actions to be taken.

Qualified Dam Safety Professional Required

All problems are potentially hazardous.